UNMANNED AERIAL VEHICLES: TRENDY TECHNOLOGICAL TOYS OR FLYING FORCE OF THE FUTURE

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Unmanned Aerial Vehicles (UAVs) are not new concepts. In fact, they flew long before the first manned flight. However, with the birth of manned aviation, unmanned projects were relegated to a subordinate position. In recent years, the Department of Defense has expressed more interest, directing priority funding and rapid employment. UAVs have been used in recent conflicts, proving successful in reconnaissance, targeting, and weapons delivery with Commanders requesting ever-increased use. The president has recognized the crucial role UAVs will play to ensure national defense. UAVs provide advantages, such as increased endurance and survivability, and decreased costs and risks to aircrew. UAV proponents say the most modern fighters, such as the F/A-22 and the developmental F-35, are likely the last of their kind, if they are ever produced at all. Even before full-rate production, the pilot is the limiting factor. Advocates envision UAVs conducting ninety percent of all combat sorties by the year 2020. A completely unmanned military flying force in the year 2025 is technologically possible, but not likely based on the uncertainty of technology advancement and on senior civilian and military direction. UAVs will likely integrate and not replace manned aircraft well into the future.

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ABSTRACT

UNMANNED AERIAL VEHICLES: TRENDY TECHNOLOGICAL TOYS OR FLYING FORCE OF THE FUTURE by Brent K. Tornga, 115 pages.

Unmanned Aerial Vehicles (UAVs) are not new concepts. In fact, they flew long before the first manned flight. However, with the birth of manned aviation, unmanned projects were relegated to a subordinate position. In recent years, the Department of Defense has expressed more interest, directing priority funding and rapid employment. UAVs have been used in recent conflicts, proving successful in reconnaissance, targeting, and weapons delivery with Commanders requesting ever-increased use. The president has recognized the crucial role UAVs will play to ensure national defense. UAVs provide advantages, such as increased endurance and survivability, and decreased costs and risks to aircrew. UAV proponents say the most modern fighters, such as the F/A-22 and the developmental F-35, are likely the last of their kind, if they are ever produced at all. Even before full-rate production, the pilot is the limiting factor. Advocates envision UAVs conducting ninety percent of all combat sorties by the year 2020. A completely unmanned military flying force in the year 2025 is technologically possible, but not likely based on the uncertainty of technology advancement and on senior civilian and military direction. UAVs will likely integrate and not replace manned aircraft well into the future.

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ACRONYMS

ACS	Aerial Common Sensor
ACTD	Advanced Concept Technology Demonstrator
AFTFP	*United States Air Force Transformation Flight Plan*
ATR	*United States Army Transformation Roadmap*
AUVSI	Association of Unmanned Vehicle Systems International
BAMS	Board Area Maritime Surveillance
C2	Command and Control
CRS	Congressional Research Service
CSAR	Combat Search and Rescue
D&TSS	Deliberate and Time Sensitive Strike
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
DSB	Defense Science Board
EO/ IR	Electro-Optical/ Infrared
FAA	Federal Aviation Administration
FCS	Future Combat System
FPASS	Force Protection Aerial Surveillance System
GAO	Government Accountability (formerly Accounting) Office
ISR	Intelligence, Surveillance, and Reconnaissance
JFC	Joint Forces Commander
JFCOM	Joint Forces Command
JPO	Joint Program Office
J-UCAS	Joint Unmanned Combat Air Systems

LOS	Line of Sight
NAS	Naval Air Station/ National Airspace System
NSS	*National Security Strategy of the United States*
NTR	*United States Naval Transformation Roadmap 2003: Assured Access and Power Projection From the Sea*
OFT	Office of Force Transformation
OSD	Office of the Secretary of Defense
RDT&E	Research, Development, Testing and Evaluation
RSTA	Reconnaissance, Surveillance, and Target Acquisition
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SBCT	Striker Brigade Combat Team
SEAD	Suppression of Enemy Air Defenses
SURSS	Small Unit Remote Scouting System
SWUA	Strike Weapons and Unmanned Aviation
TCN	Tactical Control Network
TPG	*Transformation Planning Guidance*
TUAV	Tactical Unmanned Aerial Vehicle
UAV	Unmanned or Uninhabited Aerial Vehicle
UCAR	Unmanned Combat Armed Rotorcraft
UCAV	Unmanned Combat Aerial Vehicle
UCAV-N	Naval Unmanned Combat Aerial Vehicle
UNITE	UAV National Industry Team
US	United States/ Unmanned System
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistic

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CHAPTER 1

INTRODUCTION

> We are entering an era in which unmanned vehicles of all kinds will take on greater importance in space, on land, in the air, and at sea (2001).
>
> President George W. Bush, Address to the Citadel

Background

It is important to invest now in the future. The technological advantages that the US military enjoys today are related to research and development conducted up to forty years ago. Considerable risks of loss of time, high financial requirements, protecting projects (secrecy), and security are among the considerations when undertaking a project for future requirements or developing a technology seen to be useful in the future. The age-old "form or function" question arises. Does the military have a need for which it develops a solution to satisfy that need or does it have predetermined tools and try to apply them to new needs? Depending on whom asked, the answers vary and change over time. Staying ahead of future threats, while balancing current assets and future capabilities with the proper funding for each, presents policy makers, strategists, and military leaders with a complex dilemma. These variables are of vital importance when determining the composition of the US military's future force and in particular, the future flying force. The US military has achieved unprecedented intelligence gathering, air superiority, and precision weapons delivery with manned aircraft but not without cost. Loss of life, expensive maintenance, training, and operating costs all suggest another option be considered. Does the military foresee a need to replace vulnerable and expensive manned aircraft? Perhaps it is time for a change-- not to give up the strengths that have been gained in the air, but to achieve them with less risk at lower cost using unmanned aerial vehicles (UAVs).

Long before pioneers of aviation placed man in sustained flight at the turn of the twentieth century, inventors had flown many types of aircraft. These primitive crafts in the form of airfoils, gliders, and even engine-driven craft were in development and successfully test flown much earlier than flying men, but that changed when Orville Wright sustained powered flight while aboard the *Flyer No. 2*. The future of unmanned aircraft development took a backseat while powered, sustained, and piloted flight soared. During this time, research and innovation led to experimentation and ultimately finding applications for this new flying thing. To some visionaries, who saw airliners transporting people from coast to coast, the question was would this flying thing be ready to do what they wanted it to do? To others, mostly pioneers of aviation, the question involved the full future potential of this new technology. These struggles of "here's a problem, build something to fix it" and "here's a technology, figure out how to use it," have continued throughout time.

Today is no different. Given the face of a new enemy and threat, strategy and tactics continue to change. All branches of the military are undergoing a transformation to meet these current and future threats. The United States is very interested in a future force comprised of mobile, specialized, quick, responsive, and flexible units of personnel and equipment. If you ask a pilot, "Will you be an integral part of that force," he or she will most assuredly tell you "yes." But, does that mean they will don their flight gear and walk to the aircraft? Or might they preflight a command joystick and boot up a control computer. Many changes are underway and as all services come together on a more integrated and cooperative joint team, a roadmap to prepare for the future is required. How we got to where we are today began in the early 1990s and perhaps even before. A key catalyst to current ongoing change was the publishing of *Joint Vision 2010* in 1997, which has paved the foundation for the latest pub, *Joint Vision 2020*. Chapter 2 will explain why this foundation was necessary in establishing direction for a number of future programs and new technologies including UAVs.

Before exploring the leadership direction and vision for UAVs, this chapter will provide a broad background of past use, a current snapshot, and future potential of unmanned aviation. In addition to background, this chapter will give the reader a sense of why this thesis is important, the primary and secondary research questions, the assumptions going into it, a few broad definitions, and the limitations of this research.

"Unmanned aircraft, known variously as 'drones', remotely piloted vehicles, and now unmanned aerial vehicles (UAVs), have been a feature of aviation for much of its history, though in limited or secondary roles. In the 21st century, the technology seems to be headed towards greatly expanded use" are the words of Greg Goebel and the opening two lines of a comprehensive look at the history of UAVs (2005, 1). This statement goes a long way to introduce the foundation for this thesis. Will UAVs eventually replace piloted aircraft, as we know them? Will this happen overnight? Certainly it will not. Will it even happen in twenty years? The research and analysis will yield an answer to that question.

UAVs have many names and purposes from the Predator to the X-45 JUCAV. They once were a concept, but now are a reality. UAVs have been integral assets at the disposal not only of the military, but interagency and private sector as well. US Customs, Border Patrol, DEA, CIA and private businesses have used UAVs for intelligence collection, weather monitoring, security, and surveillance for a number of years. Throughout the twentieth and early twenty-first centuries, the military has used UAVs in roles ranging from target drones to intelligence, surveillance, and reconnaissance (ISR) and even weapons delivery. Coupled with satellites and precision cruise missiles, piloted aircraft missions have slowly but increasingly been replaced by unmanned air assets. Weather, ISR, and communication relay satellites, Tomahawk Land Attack Missiles, and UAVs, like Global Hawk and Predator, are already conducting missions that a piloted aircraft had previously undertaken.

Significance

Why are so many resources and so much time being poured into unmanned systems? Might they just be a faddish novelty that will pass? The fad has not passed in over one hundred years. There is more focus now than ever before. In fact, direction from higher echelons embraces new UAV and related technologies. The president's *National Security Strategy of the United States* (*NSS*) and the Defense Secretary's *Transformation Planning Guidance* (*TPG)* focus on unparalleled military strength through joint operations, intelligence advantage, and development and rapid implementation of new capabilities (The White House 2002, foreword). One still might ask what these documents have to do with UAVs. Reviewing the *NSS* and *TPG* will answer that question. The *TPG* states that transformation involves more than just new technologies; it is a different way of thinking and operating. There must be a recognizable and measurable advantage through the transformation process forcing recognition of increased capability, at greater efficiency, than that which was done or used before.

Programs must be streamlined for rapid concept development and experimentation. In the Office of the Secretary of Defense's (OSD), *UAV Roadmap 2002-2027*, the Secretary of Defense outlined future unmanned flight operations. In the interest of national defense, enhancing future combat strength, and minimizing loss of life, the roadmap provides a Defensewide vision; directs goal-oriented timelines for areas of interest including platforms, sensors, communications, technology, interoperability, intelligence collection, weapons, and reliability; and finally identifies service and agency leads. The overall goal of the roadmap is to define clear direction to the services and Departments for a logical, systematic migration of mission capabilities to a new class of military tools (OSD 2002, iii).

During a Pentagon briefing in March of 2003, the Deputy for the OSD Unmanned Aerial Vehicles Planning Task Force, Dyke Weatherington, commented to the press "the Pentagon plans heavy investment in UAV development. The UAV Roadmap provides those high-priority investments necessary to move UAV technology to the mainstream. The potential value UAVs offer ranges across virtually every mission area and capability of interest." Secretary Rumsfeld endorses the roadmap with strong support for UAV programs and pushes their implementation as one way to transform the military (Sample 2003, 1). Toward this end, what UAVs offer that current manned aircraft might not, is gaining priority in our military force, which translates into increased funding.

Why does the Secretary of Defense place such high importance on UAVs? They have demonstrated their capabilities beyond original planning and have proven to be effective in combat. Five years ago, Congress supported the aggressive pursuit of unmanned combat systems Combatant Commanders were asking for. Because Defense funds are limited, budgets must be rooted in valid warfighting requirements (OSD 2000, 1). Combatant Commanders, unified Commander-In-Chiefs at the time, prepared a UAV mission priority list, validated by the Joint Requirements Oversight Council (JROC), that requested funding to increase unmanned capabilities in the following areas: reconnaissance, signals intelligence, mine countermeasures, target designation, battle management, chemical and biological recon, counter-intelligence and deception, electronic warfare, combat search and rescue (CSAR), communications and data relay, information warfare, and digital mapping (OSD 2000, 7). In alignment with the Secretary of Defense's high priority for UAVs, what advantages do they offer over their manned predecessors? Remember, transformation requires a distinct advantage over what or how something is currently employed.

Recognized as "dull, dirty, or dangerous," missions formerly flown by manned aircraft have transitioned to UAVs. Military leaders seek to use means other than manned flight to accomplish the 3 Ds. Dull (long dwell) missions involve monotony with long flight times and little threat danger. Dirty (sampling for hazardous materials) missions are those that may expose humans to biological or chemical danger. Dangerous (extreme exposure to hostile action) missions involve a heightened risk of serious damage to aircraft or injury to aircrew (OSD 2002, 26-27). Today more than ever, the US is a society sensitive to casualties. If diplomatic efforts are exhausted and war is the last possibility, then the US can fight a more acceptable war with a feasible, reliable, and acceptable way to minimize air training and combat fatalities. Safety is a high priority in all air operations. Although evaluating and minimizing risk is part of all mission planning, it cannot be completely eliminated. An alternative to manned air operations will help to minimize overall risk and completely eliminate the risk of potential loss of aircrew.

Perhaps the greatest advantage of an unmanned flying force is the ability to penetrate global airspace, including deep flight within enemy surface to air engagement areas, without risking aircrews. By eliminating the potential loss of life, other secondary and tertiary benefits are gained as well. By removing the onboard pilot, several physiology and life support systems can be removed which reduce weight and size. This leads to greater aerodynamic stealth design and survivability through a reduced radar cross-section and optimized performance without the limitation of a human's physical ability. Pilot fatigue, training time and cost are all reduced. Ground control stations can double as simulators further reducing the cost of training. Manned aircraft fly a majority of their flight hours outside combat due to the requirement of proficiency and currency training by pilots. The dollar per combat hour across the life cycle of an airplane or jet then is very high. A UAV on the other hand flies a majority of its flight hours in combat making it more cost effective. An abundance of training flights is simply not required. The UAV can be parked and preserved until required for its mission.

Thesis Intent and Primary Research Question

This thesis will determine whether unmanned assets will continue to augment US military piloted aircraft or replace them in the next twenty years. This question suggests some confinement and measurement tools be implemented to analyze the military's most likely future direction concerning the composition of its future flying force. Specific methods for research and analysis will be covered in chapters 3 and 4 respectively. General provisions, assumptions, and limitations are presented in the following paragraphs. This thesis will address a wide range of current and future assets both manned and unmanned from all U. S. military services. This broad and all encompassing study suggests that the research may be vague and not detailed. To counter this point, the thesis will focus on key areas, first of which is the current view of individual and collective service leaders. Simply focusing on the possibilities and potential of unmanned assets, primarily UAVs, will not answer the key thesis question. All the research and development being conducted by the government and private sector does little to support replacement if the joint vision of future use does not include a need and incorporate that technology into the future flying force. Current procurement and contracts for both manned and unmanned aerial vehicles may reveal an immediate answer to at least the current vision for composition of air assets through the next twenty years. These contracts typically have a timeline including service entry and phase out. After describing the current vision, the thesis will explore feasibility issues, focusing on strengths and weaknesses of UAVs compared against manned platforms.

Key Assumption--Satellite Reliant Network System

One key assumption is that space is integral in the wide spread use of UAVs, primarily due to the C2 requirements and secondly due to data transfer. Data transfer is important in near real time situational awareness in the application of ISR, changes in targeting data, friendly and enemy location, and battle damage assessment. Both C2 and data transfer are issues that must be addressed, however UAV reliance on satellites does not mean that satellites are considered UAVs. Satellites and cruise missiles are categorized separately. For purposes of this thesis, the term UAV will be further defined later in this chapter. As mentioned, a communications and control network involving satellites is required. Beyond line of sight, two-way communications are essential to the successful control, monitoring, and deconfliction of a future unmanned flying force. In order to manage a complex unmanned system, a network with satellites as the crucial link for basic communications requirements is critical throughout the entire process. How does one manage such a system and is there such a system in place? Is a totally unmanned flying force even possible, given this reliance on satellite C2, or will UAVs be limited only to line-of-sight (LOS) links to ground units in theater? These questions are presented now for background consideration and will be answered later during the chapter 4 analysis.

Other issues that must be addressed include multiple service use, control, monitoring, and deconfliction. Some UAVs are small, even micro, short range and remotely controlled, not requiring an extensive data link system. Others, the size of a Boeing 737, are semiautonomous requiring a sophisticated monitoring and deconfliction system. When discussing strengths and weaknesses, comparative manned and unmanned data will be assessed. Chapter 4 will address this comparison using categories such as direct cost per vehicle, costs of training operators, survivability, emergencies, operator battlefield situational awareness, endurance, and range.

Cruise missiles are unmanned weapons delivery capabilities but will not be reviewed in this thesis. An unmanned combat aerial vehicle (UCAV) may provide a more cost effective precision weapon delivery platform. After all, a cruise missile is only designed to go one way and fly only one time. A UCAV, on the other hand will travel to its objective and return again for repeated use, at a reduced cost.

Satellites and cruise missiles are not categorized as UAVs and hence will not be included in this thesis under the term UAV. They may, however, be addressed on the basis of inner-operability and any reference to unmanned air assets will include satellites and cruise missiles.

Broad Definitions

Even the term UAV has several meanings and connotations. For purposes of this thesis, Tom Ehrhard's definition from *The US Air Force and Unmanned Aerial Vehicles* dissertation at Johns Hopkins University, 1999 will be used. A UAV is a self-propelled aircraft that sustains flight through aerodynamic lift. It is designed to return and be rescued, and it does not have a human onboard. It excludes lighter-than-air craft such as balloons, blimps, zeppelins, or airships, and it rules out ballistic missiles, which do not employ aerodynamic lift to achieve flight. Lastly, it excludes cruise missiles. Although cruise missiles are closely related ancestors to UCAVs, they differ because they are one-way platforms, where UCAVs are two-way (Ehrhard 1999, 3.). This definition of a UAV, though very similar to Joint Publication 1-02, *The DoD Dictionary of Military and Associated Terms*, definition is used because it is more restrictive. As a comparison, the JP 1-02 defines UAV as "a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles" (Joint Chiefs of Staff 2000, 559).

Further, the "U" in UAV is also open to interpretation and usually is defined as unmanned or uninhabited based on application. The prime factors influencing which word is used in the role the UAV plays are the guidance system and the priority placed on the requirement of a man-in-the-loop. Man-in-the-loop is a term associated with the requirement of a thinking human integrated in the decision making process at various points in the mission. The man-in-the-loop may operate from a ground station, another aircraft, or ship; and the amount of interface varies between different concepts. Most theorists view potential future UAV missions, like Offensive Counter Air, Interdiction or Strike and Close Air Support requiring a man-in-the-loop. These types of missions and the platforms that will fly them use "uninhabited" when describing UAVs. This is because an uninhabited aerial vehicle still has a "man-in-the-loop" for friendly/ enemy deconfliction, and authorization of weapons delivery. Some theorists, however, envision fully autonomous systems launching on autopilot, flying a preprogrammed route, seeking and destroying their target, and returning to base without any human intervention at all. This vision is of a pure unmanned aerial vehicle. More often, "unmanned" is used to describe missions and platforms that are semiautonomous; for example, a mission utilizing an unmanned aerial vehicle preprogrammed for intelligence gathering flown on autopilot via an inertial navigation system or global positioning system. When the word "unmanned" is used, it is understood that these systems are semiautonomous and still require operators in some manner, be it to launch and recover, to override autopilot by radio control, or to monitor systems. For long-range applications, a sophisticated satellite control network may be necessary.

During this thesis, reference to UAVs includes missions and platforms of both unmanned and uninhabited and will be clear, based on the context and aforementioned premise of use. Reference to unmanned air assets, other than UAVs defined above, includes satellites and cruise missiles. Further definitions and a full list of acronyms can be found in the glossary (pg 106) and the acronym list (pg vi.).

Limitations

This thesis will focus on open source and unclassified information. *The Defense Planning Guidance*, one of the key publications directing employment and makeup of the US military, will unfortunately not be available to cite in this thesis due to its classification. However, *Joint Vision 2020*, service transformation roadmaps, *Concept for Future Joint Operations*, OSD's *Desired Operational Capabilities*, and the OSD's *UAV Roadmap, 2002-2027*, are all unclassified publications that will be referenced throughout the thesis. Each of the above listed publications is consistent with the *Defense Planning Guidance*.

When analyzing the positions of key leaders, especially those at the very top, obtaining actual interviews can be difficult. Also, given that it is not feasible to travel and obtain these interviews due to the school's course schedule, reliance on secondary sources will be necessary. Pentagon briefings, press releases, and periodicals frequently carry information from top leaders within the Department of Defense (DoD) that can be used to infer the stance and position taken by those key leaders. Documents, like security and military strategies, defense and transformation planning guidance, and service roadmaps that key leaders have published or endorse, also have bearing and reflect their position regarding UAVs. Some key leaders may have personal biases that are not necessarily reflected in these documents. Without the luxury of personal interaction with each key leader, general positions and inferences based on comments they have made publicly and the written documents they are responsible for, represent the next best data.

Determining a definitive answer to the thesis question will be difficult and somewhat subjective due to the uncertain future and the dependence on vision and technological advancement. Placing a timeline of twenty years from present on the thesis question limits the amount of subjective guesswork. Based on timeline projections, historical rates of technological advancement, and rapid fielding initiatives, a refined answer will be achievable.

The focus of work will not include all unmanned air assets including ballistic missiles, ballistic missile systems, cruise missiles, satellites, target drones, and decoys or other nonaviation unmanned systems, like unmanned ground, surface and undersea vehicles. It will focus on those unmanned aerial vehicles within the definition previously outlined.

The research deadline is 15 March 2005 and completion date is 30 May 2005.

CHAPTER 2

LITERATURE REVIEW

> There is no single magic bullet application for UAVs in the future. Look to the sky at the existing aircraft flying there and understand that UAV technology will change mainstream aviation forever (2004).
>
> Scott Dann, A Project Manager Speaks

Overview

Chapter 2 is comprised of five major sections. The first part of this chapter will explore some of the interesting facts related to the past, current, and future of UAVs. This exploration will highlight the unmanned technology market and how it is not just a military venture, but applicable across the spectrum, from national defense to passenger travel. It will also look at what industry advocates and visionaries are saying about their future.

The second part of this chapter will review the continual evolution in joint operations and the more recent force transformation process and the impact each has on the US military's future force. This section will begin to identify the direction of future forces and application of joint standards on individual service transformations. Although not all aspects of each document will be expanded upon, the review will include several strategic documents, including the *NSS* and *Joint Vision 2020*. The reason for exploring these documents is to show the document relationships, to establish the purpose, direction, and standards for future operations and to explain the significance of interoperability in the joint fight.

The third part of this chapter focuses on the views of key leadership regarding future operations of UAVs. It will express the views of the Secretary of Defense and positions and outlooks of Chiefs of Staff and secretary's of the services with regard to UAVs in the future force. The *TPG* and the latest service transformation roadmaps, the *United States Air Force Transformation Flight Plan* (*AFTFP*), the *United States Army Transformation Roadmap* (*ATR*), and the *United States Naval Transformation Roadmap 2003: Assured Access and Power Projection from the Sea* (*NTR*) will be referenced to bring together their views. The roadmaps highlight war fighter needs and also identify projections of desired operational capabilities that must integrate into joint objectives and standards as outlined by the *TPG*. The review of these documents will focus specifically on the needs and projected future operational capability of UAVs.

The fourth part of this chapter introduces the *UAV Roadmap, 2002-2027*. The goal of this introduction is to highlight the intent of the UAV roadmap, which is directive in nature as compared to previous versions. The roadmap provides a defensewide UAV vision, describes 49 goals, identifies a top-10 list requiring rapid capability advancement, and appoints service and agency leads along with target completion dates for the top-10 key items (OSD 2002, i).

The fifth and final part of this chapter introduces the notion that many entities are involved in UAV futures. It begins by mentioning the importance of cooperation with the private sector and then identifies two key non-DoD organizations, which directly influence future UAV operations in unique ways. These two organizations are the Association for Unmanned Vehicle Systems International (AUVSI) and the UAV National Industry Team (UNITE).

What is the Buzz? Talk of the Town

Here is the buzz. There are practically limitless sources of information involving UAVs, from their initial inception to present, indicating practically limitless future application. For instance, one source explained how, well before World War One, timer cams were developed to allow an uninhabited glider to fly a certain number of seconds in one direction before changing course. A series of these cams allowed multiple changes in course. One such flight occurred over the Potomac River in May of 1896 when the unmanned, heavier-than-air, steam-powered “Aerodrome No. 5” built by Samuel Langley flew for more than a minute (Mcdaid and Oliver 1997, p 10). Albeit rudimentary, the first preprogrammed autopilot was born. In fact, if one considers a piece of string a simple control link, it can be argued that the very first UAV or remotely piloted vehicle was a kite flown over 2,000 years ago in China (Wagner and Sloan 1982, 15). These remotely piloted vehicles were first referenced in a military application in the second century B. C. when a Chinese general used kites to triangulate the distance for a tunnel his army was digging under a besieged city’s walls (Hart 1982, 25). However, types of unmanned flight became subordinate to manned aviation after the Wright Brothers piloted sustained flight at the turn of the twentieth century. This is no longer the case in the twenty-first century. Unmanned existence is making a comeback. One example of an exploding industry no longer dominated by manned aviation is from the science department of the Economist, which predicts private UAV industry revenues in the $40 billion range by 2010 and DoD forecasted spending in the billions per year for UAVs well into the future (The Economist 2003, 1-2). Figure 1 illustrates a projection of funding for manned versus unmanned aircraft till 2010 based on historical growth rates. This indicates an increase in funding for unmanned aircraft. With strong support from the Pentagon, it is likely that the trend will continue the upward climb and possibly at a much sharper rate.

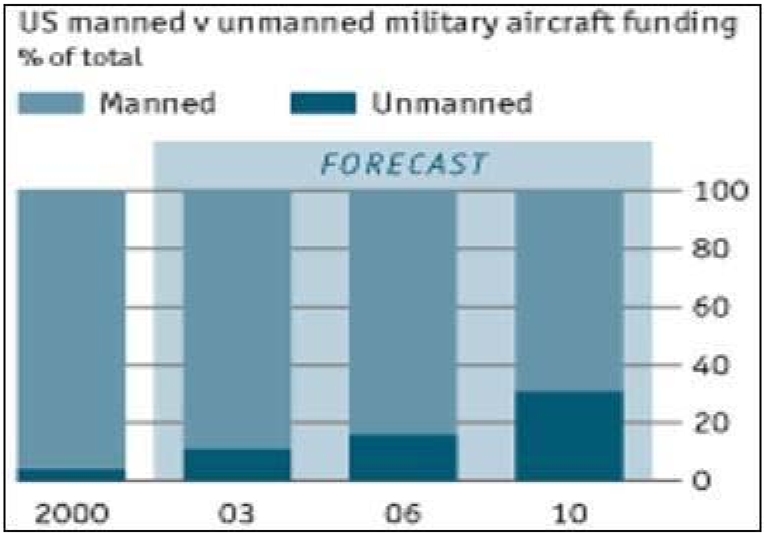

Figure 1. US Manned vs. Unmanned Military Aircraft Funding
Source: Future of Flight: High Times. *The Economist, Science and Technology*, 11 December 2003; [Website, The Economist.com], available from www.economist.com /science/displaystory.cfm?story_id=2282185. Internet; accessed 10 January 2005.

The potential of military UAVs has just barely been tapped into. Current successes mainly focus on intelligence gathering, reconnaissance, and surveillance. But all that is in the process of change. Regardless of service, UAVs are changing the way war fighters prepare for and conduct battle. The medium-altitude, endurance UAV Predator, equipped with the Hellfire missile, was credited as the first UAV with precision strike capability. The Predator demonstrated its capability by tracking and firing on mobile targets in Afghanistan and Yemen (Ciufo 2003, 67). UAVs are also being used on the battlefield for over-the-horizon scouting, imagery collection, and out-to-sea hunting submarines. They will likely supplement and eventually replace manned aircraft that conduct command and control (C2), suppression of enemy air defenses (SEAD), heavy lift, airborne refueling, and strike missions. The potential is unlimited in the private sector as well. Michael Harrison of Aviation Management Associates, of Alexandria, Virginia told the audience at the 49th annual Air Traffic Control Association Conference in November 2004 that UAVs will become commonplace in the future. “You won’t know the difference whether it is a UAV or a commercial aircraft from an air traffic control standpoint. The difference is [UAVs] are preprogrammed so the controller can at least expect it to do what it is suppose to do.” Harrison sees UAVs carrying cargo to and from commercial airports and taxiing unaided. “The technology is there,” he commented. Continuing, Harrison explained that UAVs will be used for environmental monitoring, natural resource management, on scene command and control, commercial cargo transport, remote sensing, communications, and surveillance (UVSI 2004, 1).

Three innovative officers, Lieutenant Colonel James R. Reinhardt, USA, former member of the Support Directorate (J-2), Joint Staff; Major Jonathan E. James, USAF, former staff officer US Strategic Command; and Lieutenant Commander Edward M. Flanagan, USN, former staff officer Strategy Division (J-5), US Atlantic Command, with a vision of the unmanned future, studied the trends of increased UAV proliferation through the mid-to-late 1990s. Even then, during a time when UAVs were not at the forefront of many conversations, these three officers foresaw the issues that senior military and civilian leaders within the DoD are faced with today. In the spring 1999 *Joint Force Quarterly* Military Innovation Essay Contest, three officers won first prize for their visionary article “Future Employment of UAVs: Issues of Jointness.” The article begins by stating, the future of unmanned systems depends on how they are employed--

haphazardly or synergistically. It suggests that in the future, the military will either see a revolutionary reshaping of the battlespace or an underrealized capability comprised of merely expensive toys. Two simultaneous goals of increasing munitions lethality and reducing friendly casualties can be realized, but development and employment must be balanced among needs of individual services and the joint community (Reinhardt, James, and Flanagan 1998-99, 1-4).

A couple years later on 30 July 2001, Vice Admiral Joe Dyer, Commanding Officer of Program Executive Office for Strike Weapons and Unmanned Aviation (SWUA), discussed the very same issues with the press during the first-ever public UAV show at Webster Field Annex of Naval Air Station, Patuxent River. The unmanned air show invited several defense teams and all services to participate in demonstrations before distinguished guests and the general public. Vice Admiral Dyer commented, “Webster Field has been the cradle of much of the body of knowledge about unmanned aerial vehicles. Today we’re trying to tie together the innovation and excitement of unmanned vehicles with the discipline that is necessary to deliver war fighting unmanned systems” (Morris 2001, 1). To the general public, this UAV air show might have been a gathering of reporters, contractors, and RC enthusiasts, but to many others, it was a basic introduction to a much greater capability for the future war fighter.

Proponents of an unmanned air force are intermixed throughout Congress, DoD civilian directorates, the military, and the private sector. One example from an interview with *Aerospace Daily* on 31 July, 2001 illustrates optimism from both a senior military leader and a Congressman. In the interview, Rear Admiral John Chenevey, Executive Officer of SWUA, said, “Despite current issues, Senator John Warner’s

[Republican,Virginia] proposed goal of thirty percent of all combat aircraft being unmanned by 2010 is an attainable, though difficult, one for the Navy. We're going to have to work very hard to get there, but that's our goal." Senator Warner made the comment in a brief before Congress and it was further published on 30 October 2000 under Section 220 (Unmanned Advanced Capability Combat Aircraft and Ground Combat Vehicles) of the National Defense Authorization Act, FY 2001. Subpart (a) of Section 220 specifically identifies the goal of the Armed Forces to "achieve the fielding of unmanned, remotely controlled technology such that by 2010 one third of the aircraft in the operational deep strike force aircraft fleet are unmanned" (DoD 2001, sec. 220).

Another comment comes from modern airpower theorist retired Colonel John Warden. Colonel Warden was an Air Force fighter pilot with combat experience in Vietnam, Fighter Wing Commander, and credited by Norman Schwarzkopf and Colin Powell as the architect of the Desert Storm Air Campaign. He is an executive, a strategist, a planner, an author, and a motivational speaker, who has had an impact in business, the military, government, and education around the world. After retiring, he served as a Special Assistant to the Vice President and consulting faculty at the Air Force Command and Staff College. He commented in an *Aviation Week and Space Technology* article, "[UAVs] are rapidly approaching the point where they will be able to do most things a man can do, other than untangle complicated shoot/no shoot decisions on the spot." He predicts unmanned combat air vehicles (UCAVs) will comprise ninety percent of the US air breathing combat aircraft by 2020, and maybe before (Scott 2002, 3).

These are just a few of the many comments that cement unmanned aviation, not as a concept of the past but as a reality of the future. They have changed the dynamic of aviation to date, are shifting the mind-set of senior leadership today, and will forever change the shape of military air platforms of the future. In order to achieve these goals, a well thought out plan must be in place. The plan must be clear and understood by all participants, and it must identify direction, goals, leadership roles, and deadlines with full accountability. The plan must also have a purpose and integrate emerging technology. The next two sections of this chapter begin to establish that purpose and direction.

Military Evolution: National Strategy, Joint Direction, and Transformation

President Bush’s mandate for defense transformation was “to challenge the status quo and envision a new architecture of American defense for decades to come,” a bold statement, which energized the Defense Department (OFT 2004, foreword). Military strategy begins at the strategic level guided by the US national defense strategy, military transformation strategy, and joint vision (OFT 2003, 12). Figure 2 from *Military Transformation: A Strategic Approach* illustrates these strategic document relationships.

The purpose of explaining the relationships among these documents is to establish future direction to the services, to point out the significance of increased joint operations, and to stress the importance of interoperability. It is also important to know the impact those factors have on individual service transformation within joint requirements.

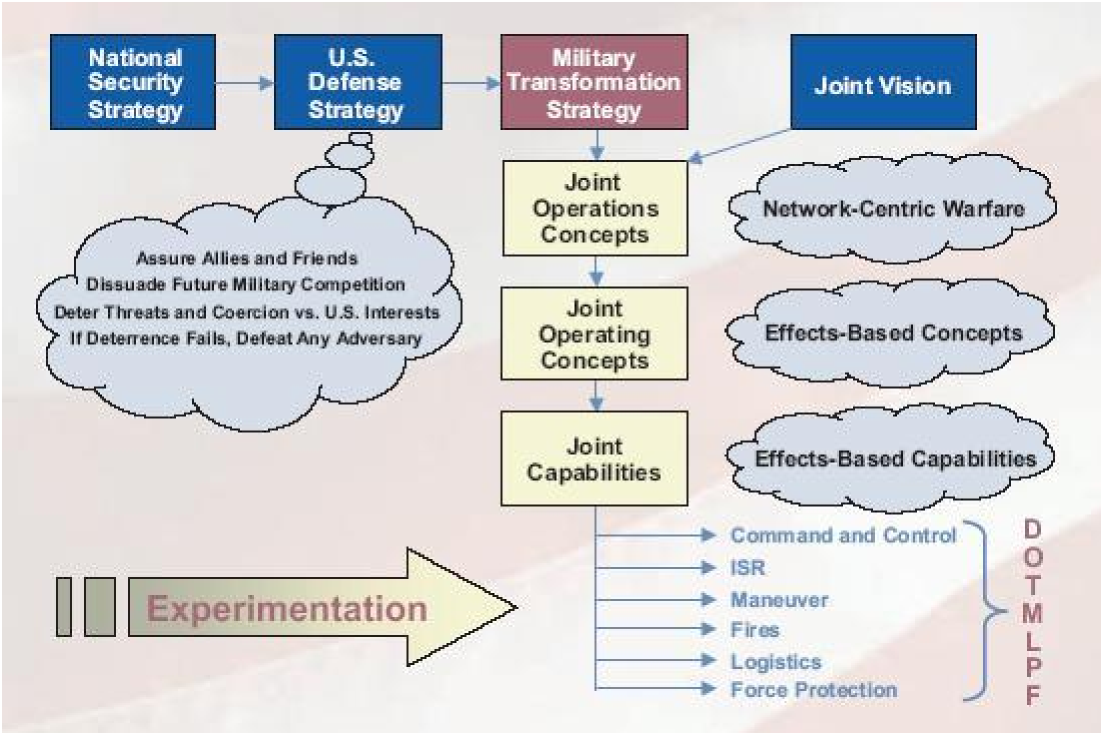

Figure 2. Military Transformation: Strategy to Concepts to Capabilities
Source: Office of Force Transformation (OFT), *Military Transformation: A Strategic Approach* (Washington, DC: GPO, fall 2003), 7.

The attacks on America in September 2001 shook the nation. The President responded by saying before Congress, the nation, and the world "Terrorist attacked a symbol of American prosperity. They did not touch its source. America is successful because of the hard work, creativity, and enterprise of our people" (2001, 1). The *NSS*, though broad in nature covering goals to secure our nation, as well as strengthen alliances, global economic growth, and democracy, was very direct and pertinent to the military. Section IX, "Transform America's National Security Institutions to Meet the Challenges and Opportunities of the Twenty-First Century," opens with the statement "The major institutions of American national security . . . must be transformed." It continues stating, “It is time to reaffirm the essential role of American military strength. We must build our defenses beyond challenge.” The *NSS*, Section IX directs the military to develop assets such as advanced remote sensing, long-range precision strike capabilities, and transformed maneuver and expeditionary forces. It also stresses the importance of innovation and experimentation; development of new approaches to warfare, strengthened joint operations, exploitation of intelligence advantages, and taking full advantage of science and technology. Of special note concerning exploiting intelligence advantage, it emphasizes that initiative must focus on investing in future capabilities and continuing to develop new methods of collecting information (The White House 2002, 30). This document is the voice of the President, direction from the highest level, from which all defense planning begins, including the linkage to all other strategic documents. Each of the above directives from Section IX of the *NSS* can be directly attributable to the increased use and dependence of US national security and military strength on UAVs. For example, advanced remote sensing, innovation, exploiting intelligence advantage, future capabilities, new methods of collection can all be seen in UAVs, like Predator and Global Hawk. New approaches to warfare, science and technology, experimentation, future capabilities, and long-range strike can all be seen in projects, like X-45 and X-47 UCAVs. UAVs provide means to the above ends.

The latest *National Defense Strategy of the United States* (*NDS*) was just recently released in March 2005. It is the most current national strategic document building upon the *NSS* but focused on how the military instrument of power can be used to achieve national security objectives. The *NDS* is published by the Secretary of Defense and provides strategic guidance in three main areas: objectives, defense policy goals, and force structure. In order to achieve strategic defense objectives, the *NDS* identifies that the military must: assure friends and allies, dissuade adversaries, deter aggression, and defeat adversaries decisively. The last main area, force structure, addresses right sizing the military to be able to respond to the challenge of defending the homeland while deterring forward in and around four regions with swift defeat of adversaries in two overlapping campaigns achieving decisive and enduring victory in one. This strategy is the “1-4-2-1” posture (DoD 2005, 1, 6-8). To achieve success, force structure must be correct and that requires a strategic plan, which can be found in *Military Transformation: A Strategic Approach*.

Preparing for the unknown amidst current conflicts may be the wrong time to transform. However right or wrong, the military has no choice. Transformation is a process that the military is undergoing and currently, is mandated by the president. The Secretary of Defense, in the *NDS* foreword said “Knowing the dedication and capabilities of our uniformed men and women . . . I am confident we will succeed” (DoD 2005, foreword). The transformation strategy involved establishment of the Office of Force Transformation (OFT), which is the primary oversight and advocate for force transformation. The OFT publishes guidance and responsibilities for the Secretary of Defense to the Joint Chiefs of Staff, Commander JFCOM, other Combatant Commanders, and all services (OFT 2004, 2-3). Its director, A. K. Cebrowski, advocates, directs, monitors, and evaluates service transformation progress and advises the Secretary of Defense on matters associated with future joint operations concepts. One specific requirement the OFT directs to the military departments is to publish a service specific transformation roadmap and keep it current as maturing technology and experimentation dictate. Evaluation of the roadmaps in the next section will focus on war fighter needs and projected future operational capabilities specific to UAVs.

Before discussing the roadmaps, it is important to point out that in addition to *Military Transformation: A Strategic Approach* joint vision also provides direction to services transformation. The military is increasingly operating in the joint environment. The latest strategic document forecasting the future fight is *Joint Vision 2020* (*JV 2020*), which projects joint operations and capabilities building on both security and defense strategies and incorporating transformation planning guidance. *JV 2020* is especially important when considering developmental and experimental programs like UAVs because interoperability requirements pushed by the Joint Chiefs and Joint Forces Command (JFCOM) may drive program considerations. This is especially true with finite budgets and competition for funding. If a new weapon system or capability cannot be "plugged in" easily or deployed within the joint realm, another option will likely take priority. The trend is to develop interoperable systems now rather than attempt a soft or hardware patch later to join independent capabilities. Just one example is the combined DARPA, Navy, and Air Force Joint-Unmanned Combat Air Systems (J-UCAS) project. Even though independent contracting teams are conducting RDT&E, interoperability standards require common operating components and systems. The independent UCAVs from each primary contracting team must also be interoperable within a common command and control (C2) system. To manage the common operating system, the J-UCAS Program Director has established the Common Systems Consortium (CSC). The J-UCAS office interfaces directly with each primary contracting team and the Deputy Program Director Common Systems and Technologies, who acts as both integrator and broker. In the integration role, the deputy director oversees development, testing, and integration. In the broker role, he serves as facilitator and oversees decision-making and configuration control (Pitarys 2004, 1, 4, 8-9).

TPG and Service Transformation Roadmaps

A key pillar in this research is the voice and stance of top leadership. This portion of the chapter will expand on transformation and expresses the positions of the Secretary of Defense and the service secretaries and Chiefs of Staff regarding the application of UAVs in the future force by referencing the *TPG* and each services latest transformation roadmap.

UAV successes have been achieved as a result of top-level intervention and innovative acquisition approaches. The OSD in 2003, for example, intervened to keep the UCAV program viable. As UAV programs grow in the future, they will face challenges in the form of increased funding competition and greater demand for capabilities. Meeting these challenges will require continued strong leadership, building on the *UAV Roadmap 2002-2027*, and UAV Planning Task Force (GAO 2004, 1-4, 7). The Secretary of Defense strongly advocates UAVs as can be seen by his direction to increase pursuit of UAV efforts, to increase priority funding for unmanned programs, and to rapidly develop, test, and field UAV systems.

In the *TPG* foreword, the Secretary of Defense states, “Now is precisely the time to make changes. . . . [We must] rethink our activities, and put that thinking into action… We must encourage a culture of creativity and prudent risk-taking . . . [to] promote an entrepreneurial approach to developing military capabilities” (DoD 2003, foreword). The first step in the transformation strategy is transforming culture through innovative leadership. Senior leaders must be committed to encouraging innovation and prepared to execute their responsibilities for implementing transformation strategy (DoD 2003, 8). Senior leader roles and responsibilities are outlined clearly in *TPG* Section IV, "Implementation of the TGP." Section IV delegates the secretaries of the military departments and the service chiefs responsible for developing transformation roadmaps, which enable support of core competencies and development of future operational capabilities. The secretaries and chiefs will also oversee experimentation and modification of operational concepts and capabilities (DoD 2003, 13).

The *TPG* lays out very specific guidance to the secretaries and chiefs regarding service transformation roadmaps. The *TPG* transformation implementation overview states that the roadmaps must demonstrate how services intend to build the capabilities necessary for executing joint operating concepts (DoD 2003, 14). This is important for two reasons. First, the roadmaps must not be self-serving but capable of participating in a Joint Technical Architecture collaborative environment (DoD 2003, 30). Second, the roadmaps will be used to help develop service POMs. Also, the Director Program Analysis and Evaluation during the annual program and budget review will use them as a measurement to evaluate the value of the POMs (DoD 2003, 14). The implication is that every war fighter need and future capability identified in the service transformation roadmaps must satisfy joint requirements and is affected and evaluated by budget decisions. These two facts begin to demonstrate why a strong tie can be made between the words in the documents and the views of the senior civilian and military leaders that endorse them. Not only are they visionary and conceptual, they must satisfy joint requirements and be justified for funding.

Some of the following senior leader positions may have changed since the publication of the service transformation roadmaps; however, when the latest versions were published in late 2003, the positions were held as identified in each of the next three roadmap studies. The views of senior leaders first examined regarding UAVs in the future force will be expressed through the words of General Schoomaker, Army Chief of Staff, and R. L. Brownly, Acting Secretary of the Army, through the *ATR*.

"We must develop a range of complementary and interdependent capabilities that will enable future Joint Force Commanders (JFCs) to dominate any adversary or situation. . . . Transforming while at war requires a careful balance between sustaining current forces while investing in the capabilities of future forces" is an excerpt from the *ATR* foreword (Department of the Army 2003, foreword). Many of the UAV-related technical capabilities for the future force that the Army is focused on involve the War Fighter Information Network- Tactical (WIN-T), the Future Combat System (FCS), the joint interoperable Battle Command System (BCS), and Critical Sensors. Of these areas, UAVs play the biggest role in the FCS and Critical Sensor capabilities. Table 1 illustrates the Army's plan to incorporate UAVs in the FCS. The following provides background information to aid in interpreting the figure.

Four classes of UAVs are identified for the FCS in the *ATR*. The Class I UAV supports the platoon level and is characterized by a backpackable, affordable, easy-to-operate, and responsive reconnaissance and surveillance system. Class I UAVs employ reconnaissance, surveillance, and target acquisition (RSTA) operations providing information directly to the soldier. Class II UAVs use low altitude flight profiles utilizing a vehicle mounted launch system. Infantry companies and Mounted Combat System

(MCS) platoons will use class II UAVs for target acquisition data and designation for line-of-sight (LOS), beyond-line-of-sight, and non-line-of-sight cooperative engagements. Class III UAVs provide fire support capability to reconnaissance detachments within combined arms battalions. They are multi-purpose assets tailorable in endurance to meet the range requirements of non-line-of-sight fires capabilities.

Table 1. US Army FCS UAV Plan for Platoon through Brigade Level

FUTURE COMBAT SYSTEMS UAVS : 2020 AND BEYOND			
System Echelon	**Operational Radius**	**On-Station Time**	**Operational Altitude AGL (MSL*)**
UAV Class I *Support Platoons*	8 km (T) 16 km (O)	50 min (T) 90 min (O) per vehicle	500 ft AGL (10,500 MSL)
UAV Class II *Support Companies*	16 km (T) 30 km (O)	2 hours (T) 5 hours (O)	1,000 ft AGL (11,000 ft MSL)
UAV Class III *Support Battalions*	40 km (O)	6 hours (T) 10 hours (0)	2,000 ft AGL (12,000 ft MSL)
UAV Class IV*** *Support Brigades* ****More than one type vehicle may be used to accomplish the mission sets for this action*	75 km (T) 400 km (O)** **Limited duration in support of operations moves	18-24 hours (O)	6,500 ft AGL (min) (16,000 ft MSL)

Source: Department of the Army, *ATR* (Washington, DC: GPO, November 2003), sec. 8-10.

Class IV UAVs support the brigade level with multifunctional RSTA capabilities including long-range, long-endurance communications relay; persistent stare; target acquisition and designation; and the ability to team with other assets to conduct reconnaissance and surveillance for the Unit of Action (Department of the Army 2003, sec. 8-10). The table indicates threshold (near) and objective (projected) measures for four Army echelons.

The other UAV related technical capability for the future force is critical sensors. Tactical UAVs will incorporate the Aerial Common Sensor (ACS) which, when networked become critical to achieve battle-space awareness for the JFC (Department of the Army 2003, sec. 8-9). “ACS provides the JFC with wide-area surveillance and precision targeting [and] fills the Army’s critical mission need for a worldwide self-deployable airborne RSTA system” (Department of the Army 2003, sec. 8-11). Figure 3 illustrates the Army’s fielding schedule for TUAVs and ACS.

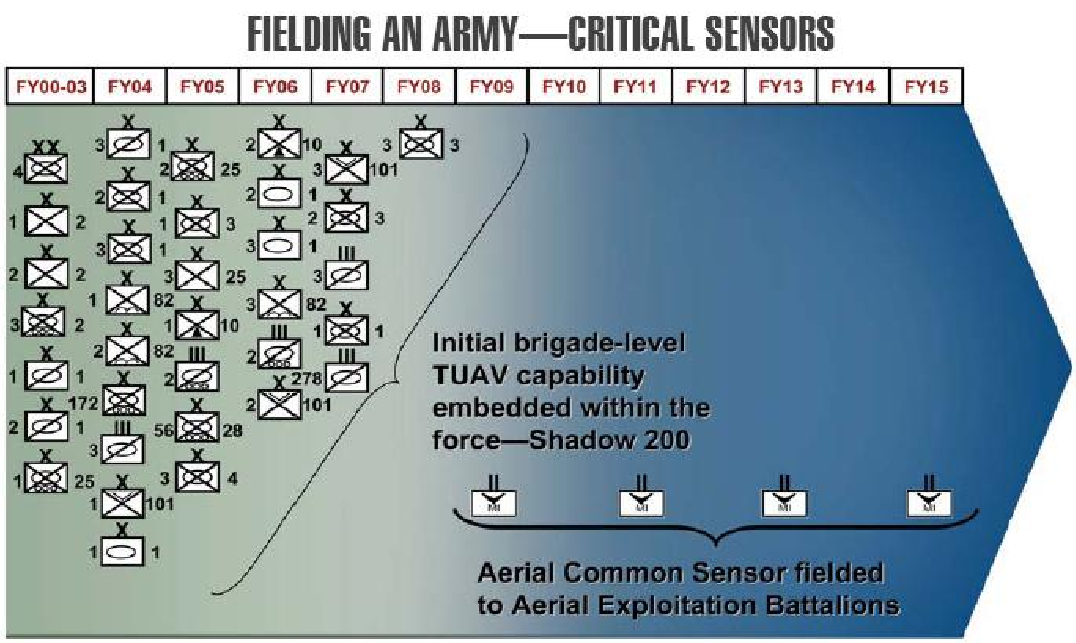

Figure 3. Army Tactical UAV and Critical Sensor Fielding Schedule
Source: Department of the Army, *ATR*.(Washington, DC: GPO, November 2003), sec. 8-11.

ACS provides the capability to see first, allowing commanders to conduct shaping and decisive operations under conditions of their choosing. “ACS sensor packages will facilitate the detection of movers, sitters, emitters, and hiders…[using] electro-optical/ infrared (EO/IR), synthetic aperture radar (SAR), moving target indicator, multi and hyperspectral imagery sensors” (Department of the Army 2003, sec. 8-12). ACS will be organic to the UA and should first be fielded in FY09.

The next views regarding UAVs in the future force are expressed by the Chief of Naval Operations Admiral Vern Clark, the Commandant of the Marine Corps General Michael W. Hagee, and the Secretary of the Navy Mr. Gordon England through the *NTR*.

“Naval Forces are unique in their contribution to the nation’s defense. Versatile naval expeditionary forces are the nation’s first responders, relied upon to establish the tempo of action, control the early phases of hostilities, and set the conditions for decisive resolution. . . . The result of our transformation will be a Navy and Marine Corps Team providing sustainable, immediately employable US combat power as part of a transformed joint force ready to meet any challenge” is an excerpt from the *NTR* foreword (Department of the Navy, 2003, foreword). Development of the *NTR* required input from both the Navy and the Marine Corps through the Naval Capabilities Development Process and the Marine Corps Expeditionary Force Development System. These processes include extensive participation by Navy and Marine war fighters to identify required capabilities (Department of the Navy 2003, 3). Although the Navy and Marines serve different purposes, and perform different roles, the *NTR* incorporates both viewpoints into common themes or pillars. The four Naval Capability Pillars are identified as: Sea Shield (defensive and protective), Sea Strike (offensive), Sea Base (method of exploiting the maneuver space provided by control of the sea), and

FORCEnet (advanced network architecture integrating sensors, decision aids, weapons, warriors, and support systems).

The *NTR* identifies unmanned systems capabilities within each pillar spanning all spectrums of sea (unmanned surface and undersea vehicles), land (unmanned ground vehicles), and air (Broad Area Maritime Surveillance (BAMS) UAV, vertical takeoff and landing tactical UAV, joint-unmanned combat aerial systems (J-UCAS), J-UCAS Naval variant, small unit remote scouting system (SURSS), and the coastal battlefield recoinnassance and analysis (COBRA) system). The pillars that identify the majority of naval UAV requirements are Sea Shield and Sea Strike.

Sea Shield involves capabilities that extend not only throughout large maritime areas but also overland to protect joint forces and allies ashore (Department of the Navy 2003, 4). Sea Shield specifically involves air and missile defense (AMD); undersea warfare including antisubmarine, mine, and antisurface warfare; and Force Protection both afloat and naval installations ashore.

Sea Strike is the offensive capability to project dominant and decisive power from the sea. It involves long-range aircraft and missile fires, covert strike, high-tempo maneuver, naval surface fire support, maritime special operations, and information operations.

Within each subset of Sea Shield and Strike, the *NTR* has developed a systematic approach to implementation by first introducing terms, capabilities, and requirements followed by concepts, experimentation methodology, timelines, and funding. Each timeline includes planned sea trial activity dates, funding requirements, component initial operating capability and full operating capability projections. For example, the first subset of Sea Strike is deliberate and time-sensitive strike (D&TSS). The *NTR* begins by introducing an overview, capabilities, and requirements including statements about what is expected or required of D&TSS in the future (Department of the Navy 2003, 40-41). "Targets will be identified more rapidly and effectively through enhanced, networked, persistent ISR systems. Netted fires and automated decision aids will accelerate the mounting of precision attacks on critical targets with appropriate precision strike means in order to produce appropriate effects" (Department of the Navy 2003, 40). The introduction also states, "Forward deployed naval assets will increasingly employ unmanned vehicles such as UAVs and unmanned undersea vehicles… dramatically expanding the commanders options" (Department of the Navy 2003, 41). Planned sea trial activities involving concept studies, field experimentation, operational prototyping, and demonstrations began across all elements of D&TSS transformation in 2004.

Figures 4 and 5 display key elements of D&TSS transformation and programs supporting D&TSS transformation broken down by timeline and funding. In figure 4 observe the categories of "Detect/ Identify/ Track" and "Engage/ Attack/ Assess" that involve extensive UAV requirements. The "Decide/ Task/ Relay" category does include input from unmanned sensors but is largely comprised of networks, computing systems, and operator integration. The following are definitions and explanations which aid in interpreting figures 4 and 5: Avionics and Communications Systems (ACS) are systems providing uninterrupted secure relay and communications; broad area maritime surveillance (BAMS) UAV; ground weapons locating radar (GWLR) includes space, manned, or unmanned aircraft based radar for detection of ground weapons; multimission maritime aircraft (MMA) is currently, a manned multimission concept based on a Boeing

737 platform (could potentially be unmanned); vertical takeoff and land tactical UAV; J-UCAS; SURSS UAV; nuclear guided missile submarine (SSGN) is a submarine that carries tactical missiles and is capable of transport and support of special operations forces (also employs a number of unmanned systems like unmanned surface and undersea vehicles, and UAV autonomous and in cooperation with SOF); joint strike fighter; and high mobility artillery rocket system (HIMARS).

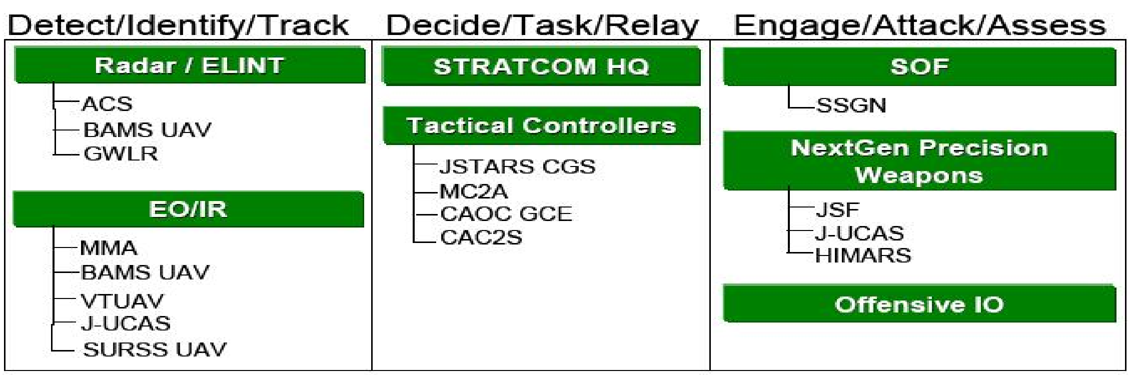

Figure 4. Key Elements of Deliberate and Time-Sensitive Strike Transformation
Source: Department of the Navy, *NTR* (Washington, DC: GPO, November, 2003), 42.

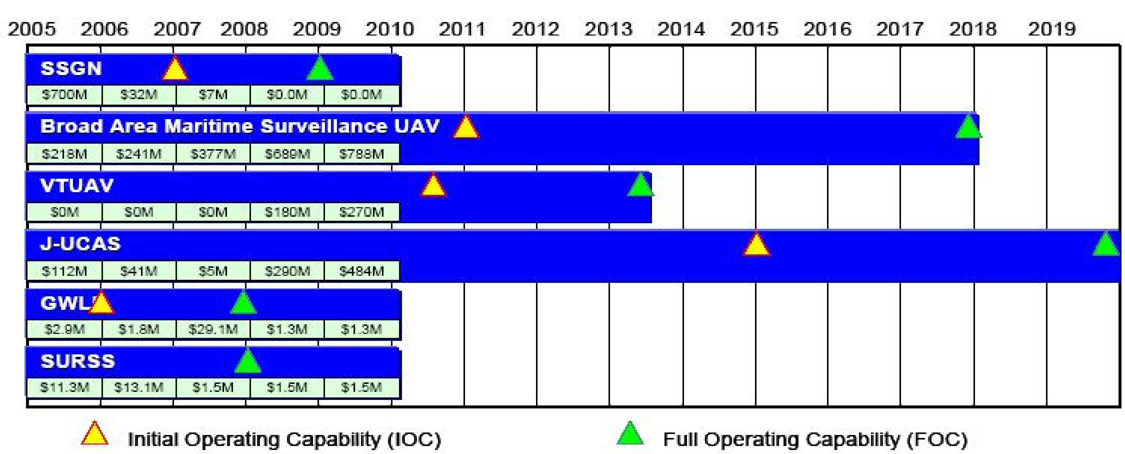

Figure 5. Programs Supporting Transformation of Strike: Detect/ Identify/ Track
Source: Department of the Navy, *NTR* (Washington, DC: GPO, November 2003), 43.

To implement the *NTR*, four focal areas are identified. The first focus is on transforming the people and the culture of the Navy and Marine Corps team. This process called Sea Warrior, transforms the human resource component of Naval Forces into a better trained, educated, and motivated warrior. The next focus is Naval support to Joint concept development and experimentation. The Navy and Marine Corps team is developing concepts in harmony with joint requirements providing for a more synchronized and interoperable force. The next focus is on science and technology. “Technology, when integrated with new operational and organizational constructs, is a critical element of transformation for the fleet. Leveraging technology is the key to both force modernization and transformation to preserve the decisive US advantage across the range of military operations” (Department of the Navy 2003, 91). The final focus is Sea Enterprise. Sea Enterprise is essentially a look at how to improve and operate more efficiently, a streamline of Naval business processes. It is “the flagship effort for freeing up additional resources to support military transformation” (Department of the Navy 2003, 93). These are the keys to implementing Naval transformation: who will do it (people), supporting who (joint), how (science and technology), and with what (structure and resources).

The final senior leadership views regarding UAVs in the future force are from the Air Force Chief of Staff General John P. Jumper, and the Secretary of the Air Force Dr. James G. Roche through the *AFTFP*.

“New national security realities . . . as well as historic opportunities to exploit revolutionary technology underscore the absolute necessity of transforming our military capabilities. . . . Systems or capabilities based on arguments that do not consider the emerging joint character or the asymmetric nature of warfare will find themselves obsolete, irrelevant, and candidates for elimination" is an excerpt from the *AFTFP* foreword (Department of the Air Force 2003a, foreword). The Air Force is transforming from a platform-based garrison force to a capabilities-based expeditionary force. To achieve the capabilities-based transformation shift, the Air Force has adopted six new concepts of operations: Global Mobility, Global Response, Global Strike, Homeland Security, Nuclear Response, and Space and C4ISR. The *AFTFP* combines two schools of though throughout its continual process of transformation. First, the current transformation is a "revolution in military affairs," or "a dramatic increase in combat capability that changes the rules of the game and renders the status quo obsolete" (Department of the Air Force 2003a, 6). The second school of thought is the current transformation is a restructuring from a Cold War force to a post Cold War force, which involves a whole host of new challenges. For example, unpredictable threats, adversaries employing asymmetric strategies incorporating new technologies, and non-state adversaries.

Desired capabilities must be identified to achieve capabilities-based transformation. The *AFTFP* has identified sixteen capabilities, of which over one-half can be linked to UAVs. The Air Force has already seen significant gains in advancing nearly all of the identified sixteen capabilities as was seen in unclassified lessons learned analysis post Operation Iraqi Freedom. Key examples include improved joint operations, time-critical targeting, and battlefield UAV employment.

Other than improvement to existing and experimental system components like propulsion and sensors, the UCAV, advanced UCAV, and seamless machine-to-machine integration and C2, it is difficult to glean precise transformational goals with regard to UAVs from the *AFTFP* for two reasons. First, UAVs already play such an active role in the Air Force from Global Hawk, Predator, and Desert Hawk, to many experimental projects. In fact, everywhere the *AFTFP* mentions air capabilities, it mentions both manned and unmanned. Second, the *AFTFP* is very strategic in nature. It allows for new ideas, concepts, and experimentation based on alignment with the identified capabilities and operations concepts. It is meant to be a guide and not be restrictive. Innovation and exploiting science and technology are mentioned as limitless pursuits to Air Force transformation and that transformation is viewed as a philosophy in which it has already been actively involved.

The *AFTFP* execution revolves around three core competencies: developing airmen, integrating operations, and technology-to-warfighting. The Air Force will ensure its people receive the education, training, and development required to continue to be the ultimate source of air and space combat capability. It will fuse its people with a wide array of platforms to maximize air and space power. And finally it will translate vision into operational capability to prevail in conflict and hedge technological surprise (Department of the Air Force 2003a, ii).

The points brought out by the service transformation roadmaps do not reflect all priorities and capabilities expressed by the military departments. However, the points highlight the reliance on UAVs that future systems will require as expressed by the inputs of war fighters through the vision of senior leaders. The next section, the *UAV Roadmap 2002-2027*, introduces the Defense Department’s plan to achieve the projected UAV goals as just described in the service transformation roadmaps.

UAV Roadmap

This exploration will address the *UAV Roadmap 2002-2027*, and highlight key issues and differences it has over past versions referred to as UAV master plans. This is only an introduction to the roadmap, which will be discussed in greater detail in chapter 4. This introduction will, however, include the Defense Department's purpose for establishing the UAV Planning Task Force, the body responsible for publishing the UAV roadmap.

The Secretary of Defense stood up the UAV Planning Task Force in 2001 to establish a plan for managing the DoD's UAV development and fielding efforts. The Task Force was responsible for promoting a common vision for UAV-related efforts and establishing interoperability standards (GAO 2004, 1-2). After a comprehensive study encompassing nearly two years, the UnderSecretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)) E. C. Aldridge Jr., and the Assistant Secretary of Defense (C3I) John P. Stenbit released the *UAV Roadmap 2002-2027* to provide a defensewide vision for UAVs with optimism to launch a new set of capabilities and options for military and civilian leaders. It is goal oriented and directive in nature, differing from previous versions that did not clearly define goals, assign leadership roles, and demand accountability for timelines. The document was published for unlimited distribution and made widely available to industry and allies. The roadmap complies within national directives, commits to a transforming military, and promotes a common vision for future UAV efforts. It is a living document that will be updated as technologies and programs mature.

Nine days after the roadmap was released, Dyke Weatherington, Deputy, UAV Planning Task Force commented to the House Armed Services Committee, “The DoD is excited about the opportunities unmanned technology offers as the department transforms to meet future threats and provide more efficient methods to conduct military operations” (2003, 1-3). Mr. Weatherington told the committee the roadmap’s purpose is threefold. First, it helps provide options to senior decision makers in development of broad strategies. Second, it helps define near-term resource allocation decisions in concert with the *Defense Planning Guidance*. And third, it identifies the highest value areas for independent investment and areas for international cooperation (2003, 2-3).

The last section of this chapter introduces a few of the many organizations external to the DoD that are participating in the future of unmanned aviation.

Who Are the Other Players and What Are They Saying?

The players are many. There are literally thousands of technology-based manufacturers and defense contracting companies. Of course, at the top are affixed companies like Boeing and Northrop-Grumman, but several others have cooperatives with vital supporting roles, such as General Dynamics, Rolls Royce, General Electric, and Ratheyon. These companies, when working under an assigned parent contract company for a major project, are often referred to as defense subcontractors. They often work on emerging technologies in support of components required for complex unmanned systems and their associated control networks. Contractors and private sector companies comprise just one set of the many players involved in the unmanned future.

The next set of non-DoD players include two organizations which promote and influence the future of UAVs, the Association for Unmanned Vehicle Systems International (AUVSI) and the UAV National Industry Team (UNITE).

The AUVSI is the world's largest nonprofit organization devoted exclusively to advancing the unmanned systems community. The organization with members from government, industry, and academia is committed to fostering, developing, and promoting unmanned systems and related activities (Association for Unmanned Vehicle Systems International 2005, 1). The association sponsors symposiums, competitions, air shows, conferences, and demonstrations and is one of the best collaborations of news, information, and events covering not only UAVs but also other unmanned systems like unmanned underwater crafts and unmanned ground vehicles. The association's homepage, Unmanned Systems Online, has a forum with AUVSI staff articles posted daily with the ability to reference archival information. As an example, one such article from November 2004 chronicled a new software load that was successfully tested throughout ground taxi and flight operations of Boeings X-45 UCAV. The software update included "Automated Dynamic Mission Replanning," a function, which allows the UCAV to respond to pop-up threats during flight, send a recommended new course to the pilot-operator, and then with operator concurrence shift course until the threat is no longer a factor before resuming course again (AUVSI 2004, 1-2). The association has ten chapters and is staffed with professional writers knowledgeable in the unmanned field. The Unmanned Systems Online homepage (www.auvsi.org) also includes links to several related sites including unmanned air, ground, sea, and other useful links, like robotics, engineering, and defense sites. The AUVSI is perhaps the best nonprofit organization and promoter of unmanned futures.

The other influential organization is the UNITE Alliance. This organization is a partnership of six major US companies, AeroVironment, Aurora Flight Sciences, Boeing General Atomics Aeronautical Systems, Lockheed Martin, and Northrop Grumman, who have put aside their differences to pursue the goal of safe UAV flight in civil airspace. These companies realize that cooperation is paramount to achieve this complex and monumental goal. If the UNITE Alliance has their way, in a few years pilots may be hearing calls from air traffic controllers like “United 2712 Heavy, traffic two o’clock and 6 miles, a Global Hawk unmanned vehicle; it has you in sight” (Laurenzo 2004, 32). UNITE was established in early 2002 when the six companies formed an alliance. Later that year a proposal was made to NASA, which evolved into the “Access 5” Project. Access 5 is a coordinated national activity initiated by the UNITE Alliance which also involves the National Aeronautics and Space Administration, the Federal Aviation Administration (FAA), and the DoD. Access 5 is a four-stage project that plans to integrate safely controlled unmanned flight with commercial traffic within the National Airspace System within five years. The project began a year ago in the spring of 2004 and is in the first of four stages expected to take about eighteen months each (Laurenzo 2004, 35). During the first stage, the goal is to clear high-altitude, long-endurance UAVs to operate above 40,000 feet. The second stage would clear flight above 18,000 feet, one of the most congested air traffic altitude blocks. Both stages would require UAVs to take off and land at restricted airports and climb to altitude in restricted air space, separated from civilian traffic. Stage three involves clearance of UAVs to file and fly on instrument flight plans operating from designated civilian airports with climb and descent clearance within the flow of civilian traffic. The final stage clears emergency UAVs to land at the nearest UAV capable airport, instead of potentially ditching in a military restricted area (Laurenzo 2004, 35).

The UNITE Alliance and the Access 5 Program have full DoD support. Scott Dann, UNITE President and Co-Manager of Access 5, reflects, “The coming of UAVs will likely prove to be one of the most dramatic and visible changes in air transportation since the introduction of the jet engine” (Dann, 2004, 1). His viewpoint is largely commercial but is important in the overall future of UAV operations. Dann also comments that the technology exists and Airbus has already committed to producing aircraft that are optionally piloted. Further, fully autonomous aircraft could evoke a revolution in the air cargo industry (Dann 2004, 1).

Not only are the Defense Department’s UAV efforts ramping up, but so too are civilian and commercial applications. The six technology companies that comprise UNITE, along with their Access 5 partners, are investing heavily in the unmanned future with not only several million dedicated dollars but untiring efforts as well.

CHAPTER 3

RESEARCH METHODOLOGY

> The object of all work is production or accomplishment and to either of these ends there must be forethought, system, planning, intelligence, and honest purpose.
>
> Thomas A. Edison

In order to answer the proposed research question, both sides of the manned and unmanned proposition must be considered. The analysis in the next chapter will include a collection of background information pertaining to manned and unmanned aviation, current status and issues with manned and unmanned aviation, future direction and plans for unmanned futures, roadblocks and limitations to a completely unmanned flying force, and a recap of chapter 2 information that directly influences the composition of the future flying force. The goal of the next chapter is to analyze a compilation of data in order to propose the asset composition of US military air forces in the year 2025. All data required to make the proposal will have been presented in the first four chapters. Chapter 5 will illustrate the proposed 2025 flying force followed by explanations, implications, recommendations, and finally closing remarks.

The analysis in chapter 4 will encompass a large amount of information. In order to organize the data, the analysis is separated into nine parts. Parts 1-6, and 8 will present new information, part 7 will recap key points from chapter 2 that influence the composition of the future force, and part 9 will summarize the data and transition to the proposed 2025 air forces composition in chapter 5. The next several paragraphs present the topics and types of information gathered and analyzed in the various parts of the next chapter.

The fourth chapter opens with an introduction of terms like strategic attack and counter air. These terms are operational functions of airpower, which will be used to introduce issues that face the current aircraft and aircrew that fulfill these roles. These functions will also be used to categorize the proposed 2025 aircraft. UAVs of today are currently employed in some of these functions. UAV concepts and experimentation are prevalent across all operational functions of airpower; however, projected timelines for implementation of unmanned platforms that will fulfill some of these functions stretch into the considerable future. Reviews of experimental UAV projects and their timelines are covered in a later part of the chapter.

Issues facing the future of current and experimental manned aviation will then be considered, followed by issues facing current and experimental unmanned aviation. Issues will be divided into three categories for manned aviation: issues specific to manned platforms, functions, and aviation today in general. The status and issues with current UAV systems will then be presented by system in two parts. First, operational UAVs, like the MQ-1 Predator and the MQ-7 Shadow, are presented followed by experimental UAVs, like the RQ-8 Fire Scout and the UCAV X-45. Each system review will provide a projected timeline for initial operating capability and FOC and whether the UAV has been used in combat effectively or not as an experimental system.

The fourth part will include an update from the Director of the Joint Air Force, Navy, and DARPA J-UCAS program. This program is highlighted because it is the largest unmanned system development ever undertaken by the DoD. It involves several partnerships in addition to the Air Force, Navy, and DARPA. Bringing independent teams together for a common purpose with several common operating systems demonstrates the DoD and Aerospace contractors are committed to UAV futures.

The fifth part studies goals, assignment of responsibilities, and timelines identified in the *UAV Roadmap 2002-2027*. Along with the roadmap, studies conducted by the United States General Accounting Office (GAO) and the Defense Science Board (DSB) will be reviewed to evaluate whether current UAV directives, goals, and programs highlighted in the roadmap are on time to complete those directives and goals. These studies also address whether the goals and directive of the roadmap are still valid or require further review. The OSD UAV goals including platforms, sensors, communications, technology (propulsion, survivability, sensors), small UAVs, standards, airspace, task and use, weaponization, and reliability identified in the roadmap are categories that the GAO and DSB shed either optimism on or suggest room for improvement.

The sixth part of the analysis chapter will evaluate the Tactical Control Network (TCN), which will be responsible for UAV C2 and payload management. This part of the chapter introduces the idea that such a robust network will be highly reliant on satellite communication (SATCOM). A topic that is closely related to the network is deconfliction and part of tackling the deconfliction challenge involves an airspace management plan. The OSD, in cooperation with the FAA, published the *Airspace Integration Plan for Unmanned Aviation* in November 2004. This plan is integral to wide spread DoD and commercial unmanned aviation and is introduced as another indicator of recognizing an ongoing fundamental change in aviation.

The seventh part recaps highlights from chapter 2 that directly impact the composition of the future flying force. These highlights from chapter 2 are industry trends, military service needs, joint force direction focused on interoperability, DoD direction, and the posture of senior leadership. An example of just one of these highlights is how industry influences the US military direction adopted throughout its continual transformation and how that direction may be influenced by private UAV industry trends, thus affecting DoD UAV funding, research, and experimentation. Defense contractors also influence DoD leadership and vice versa. This was the case when the Defense Department rewarded Boeing with contracts for experimental unmanned systems for assisting the DoD in funding research, development, testing, and evaluation (RDT&E) (OSD 2002, iii-iv, 64-65). Boeing has also recently created an unmanned aviation division, which is researching the future potential of unmanned systems, taking a portion of the financial burden away from the Defense Department (Boeing 2001, 1). Defense industry trends and relationships do play a role in the direction of the future force.

Part eight will present roadblocks and limitations that might preclude rapid advancement toward a completely unmanned military aviation force such as the reluctance of political leaders, the simple mind-set opposed to change or opposition to investing in an unproven system. Or consider that some technologies that will be depended on for future systems have yet to be developed. These are but a few of the obstacles that must be negotiated.

After establishing the vision from leadership, complying with transformational direction, reviewing trends, considering platform and function issues, showing UAV roadmap projections, forecasting injection of new technologies, and considering the roadblocks and limitations, a collaborative “what does it all mean” will be presented in the final part of the analysis chapter.

From this analysis, a proposed future flying force in the year 2025 will be presented in chapter 5 including explanations, implications, and recommendations followed by concluding remarks.

CHAPTER 4

ANALYSIS

> UAVs are among the essential, high-tech assets needed to win the war against terror (2002).
>
> President George W. Bush, *NAVAIR News*

Operational Functions of Airpower

The goal of the first part of this chapter is to provide baseline information about the functions of airpower as defined by Air Force Doctrine Document 1, *US Air Force Basic Doctrine*. These functions will be used to identify current and future issues that face the largely manned force of today and also to group like aircraft for the proposed 2025 air forces. Definitions can be found in the glossary.

The *US Air Force Basic Doctrine* states that an operational function of airpower should be a war-fighting task (not an administrative task) and that it should describe a finite operation that delivers airpower to the Joint Force Commander (JFC) (Department of the Air Force 2003b, 47-48). Although other services may have additional functions, like the Navy's carrier defense or Army's battlefield medical evacuation, they can generally be assigned to one or more of the functions described by Air Force doctrine. Air Force doctrine defines seventeen total air and space power operational functions. Of these, twelve relate specifically to air operations and will be considered when discussing air issues and the 2025 air force proposal in the next chapter. Although elements of other services may have special requirements and perform slightly different roles, together they comprise the means by which the service air forces accomplish air-related missions. The twelve functions are: strategic attack, counterair, counterland, countersea, information operations (IO), combat support, command and control (C2), airlift, air refueling, special operations, ISR, and CSAR. Specific issues facing some of these functions, as well as broad issues facing manned air operations, and specific platforms will be discussed in the next section and will be revisited in the next chapter also.

Manned Aviation Issues

A host of manned aviation issues have senior officials rethinking traditional employment of airpower, most of which are not abrupt but have been developing over time. Cost is always an issue but first an illustration is presented on how culture can influence major military decisions. For example, many factors emerging from social and cultural inputs affect major military decisions. American society strongly influences the military and can be a deciding factor between success and failure of a campaign. Dumb bombs may in fact achieve a tactical win by eliminating a target but unintended collateral damage may claim several civilian casualties. This in turn may cause public opinion to dissipate potentially leading to a strategic failure. Another example is putting troops in harms way for longer than anticipated. Exposing soldiers to combat for longer durations will likely result in more casualties, again leading to decreased public support. An illustrative third example involves a flight crew, who are hit by enemy fire and forced to eject over enemy territory. One crewmember is killed in action with an impact fatality; one crewmember, badly wounded during the missile impact or during ejection, is recovered by enemy forces and reported as dead; and the two remaining crewmembers, one of which is female, are captured and taken prisoners of war. Not only is it difficult to hear of fatalities, but now service members are in the hands of the enemy and it is uncertain if they will ever be seen alive again. Serious social-political pressure is applied in situations such as these. This pressure is likely to continue and increase, placing additional stressors on the armed forces to not only achieve decisive victory but also protect against the loss of service member and civilian lives. Concerning this issue, Major General Michael Kostelnik, former Commander of the Air Armament Center at Eglin Air Force Base, Florida states, “During the Vietnam War we were losing hundreds of people a week for a long period of time. . . . In general, people accepted this as the price of war. The same was true of Korea and World War Two. . . . Today, expectations have changed. We fought Desert Storm in 1991 and lost well under 200 people, but now that we have fought that war, we are victims of our own success. Now, society wants us to fight over-powering engagements like Desert Storm and not lose anybody” (Clark 1999, 69).

Defense spending is always a concern. How will America pay for it, and what is “it” that America will pay for? Service members have all heard “do more, with less!” The armed forces have downsized tremendously since the conclusion of the Cold War and the absence of a competing superpower. Commenting on the subsequent shrinking of the defense budget Lieutenant General Robert Raggio, a former F-22 Systems Program Director said, “We are transforming from a military of effectiveness to a military of efficiency” (Butler 2001, vii). Today the military operates with global engagements at a higher operations tempo than it did at the height of the Cold War under a more constrained budget. Do more with less is forcing leaders to constantly reevaluate where the dollars are going for future forces. During a March 2004 senior Marine Corps round-table discussion at the Command and General Staff College, Fort Leavenworth, Kansas, a retired lieutenant general commented about the complex realm of defense spending, stating that weapons systems compete for dollars and the Marine Corps has put a bundle into the joint strike fighter. The following reflects a summation from his comments on the subject. Where the military puts precious dollars can be risky business and a level of risk is assumed with all appropriations. Investing in a thirty-year project now may prove eventual success but assets today still need to function and an answer must still be found for the twenty-year requirement question as well. Even though a concept to tackle that twenty-year problem may exist now, there is simply not enough funding to robustly finance the current force, the twenty-year requirement, and requirements beyond. Weapons systems will continue to compete for dollars and this is a constant struggle. With each choice to increase funding in a certain area, risk is assumed elsewhere. Unmanned systems also compete for dollars, the same dollars. The difference is they compete with the advantage of efficiency, reduced cost, and increased effectiveness. The round table discussion, despite being non-attributable, provides a glimpse of beltway budgetary concerns at very senior levels.

Another issue facing manned aviation today is aging airframes. Even the latest generation fighters like the F-15, 16, and 18 are among the dinosaurs like the B-52, H-53, and C-130, which have either been extended beyond their initial life expectancy or have out flown flight hours allotted for their basic airframes or both. Most, if not all, currently employed airframes are facing airframe fatigue. Individual platform issues will be addressed in further detail in a later section.

Yet another issue facing manned aviation is proficiency training required by pilots. This one issue alone involves several aspects. In order for pilots to remain instrument rated, they must meet certain annual requirements to stay qualified to fly at all. Though some hours can be logged from simulation, actual flight time must be logged as well. Flying actual aircraft, typically the same aircraft that will be flown in combat further reduces lifespan and the majority of flight hours flown per airframe are not flown during combat. Airframes not requiring extensive non-combat proficiency flight will last much longer. Also, often times, squadrons that are either preparing for deployment or just coming back will give up assets to other squadrons that are deploying soon. Keeping pilots qualified and current with aging assets is a constant challenge for not only squadron readiness officers but for individual pilots themselves.

The issues that affect operational airpower functions relate to more than just one category. For example, aircrew fatigue over long-range or long-endurance missions could affect SA, Counterair, land and sea, Airlift, and ISR. Strategic flights often initiate from the US, fly enroute to theater, deliver payload, and then return to base. A typical flight could extend upwards of twenty to thirty hours, greatly fatiguing aircrew. A long-endurance mission may not cover the amount of miles that a long-range flight covers but could extend on station for an lengthy period of time, which may require multiple trips to a tanker for air refueling due to aircraft limitations. These missions can be fatiguing to aircrew as well. For example, a typical carrier strike involves mission prep, flight brief (usually two to three hours prior to launch), manup and startup (one hour prior to launch), finding a tanker prior to entering enemy country to top off fuel, flying in country to conduct the mission, returning to tanker post-mission to top off once again before returning to the carrier and preparing for recovery, followed by intelligence and flight debriefing. It is not uncommon to tank yet again before recovery especially at night and in unfavorable weather. From brief to conclusion of debrief, twelve hours may pass, with in excess of eight hours in the cockpit. Instructing a class of advanced strike student naval aviators and reflecting on a 1999 Persian Gulf deployment in support of Operation Southern Watch, LCDR Dave Souza, an EA-6B pilot and Landing Signal Officer commented, “With all that is required, a typical mission can be physically demanding, but the real challenge isn’t the flight planning, briefing, tanking, rendezvousing with other aircraft, finding the target, firing a missile, or even avoiding getting shot down. No, the real challenge is returning to Mom [the aircraft carrier] when you are completely wiped out for that pitch black night trap” (2001).

Other issues related to airpower functions involve missions deemed “dull” (ISR, Air Refueling, SA (en-route and return to base phases)), “dirty” (Reconnaissance, Interdiction amongst a known or unknown CBR threat), and “dangerous” (almost all, but especially SA, counterair, counterland, countersea, and CSAR). Chapter 1 mentioned that these missions were prime fills by UAVs. Their monotonous nature make them challenging for manned flights which could lead to complacency, fatigue, and aircrew error. The risk of either a CBR or antiaircraft threat could also lead to loss of aircraft and aircrew.

One could pick any airframe and write a complete thesis on the issues related to just that one platform. Listing all the issues with each manned platform is beyond the limitations of this thesis; however, two examples will highlight some of the true problems the aviation community faces every day, be it specific to one platform or across the board. All airframes, operational, limited rate production, and experimental, have issues, such as aging airframes, lack of engine replacement, reliability, or cost. For example, mishaps and cost have riddled the U-2 Dragon Lady program over its lifetime.

Designed in secrecy by the collaborative effort of the US Air Force, the Central Intelligence Agency, and the Lockheed Corporation, the U-2 was built for gathering intelligence and reconnaissance during the Cold War, first taking flight in 1955. Its motto “In God we trust, all others we monitor,” fitting of the Cold War era, was in line with the Eisenhower authorized and Soviet rejected “Open Skies” plan allowing over flight of each country’s airspace. Cost over the fifty year lifespan, most of which is still classified, has been an issue from before inception. During the onset and throughout the Cold War, defense expenditures related to issues directly influencing the security of the US, like the U-2 program, soared. The actual costs, unknown to most due to classification, would grow continually and be realized over time. Sophisticated platform, life support, and sensor systems were initially expensive and continued to rise. The U-2 has evolved through many upgrades. EO/IR sensors, upgrades in fuel, electromagnetic interference reduction, crash survivable cockpit data recorder, airborne information transmission system (ABITS), and life support systems have all upgraded the U-2 capabilities but at a cost. Most platforms eventually reach a point of diminishing returns when it becomes cheaper to rebuild a modern platform than continue to upgrade. In addition to cost, there have been almost as many class A mishaps (22) in its lifetime as there are platforms in the current inventory (27 operational), which until recently were never released to the general public or entered into the Safety Centers database (Federation of American Scientists, 2005b).

According to a CRS report, many factors indicate that the unmanned Global Hawk or a combination of multiple UAV ISR platforms will replace the U-2. Some reasons listed include being “notoriously difficult to fly,” possessing unforgiving handling characteristics at altitude and precarious landing situations with intentional near stalls and dragging of the wingtip down the runway after touchdown. The Air Force has had difficulty maintaining an adequate supply of U-2 pilots because of the demanding physical rigors and aptitude required (CRS 2000, 5-6). Also, the U-2 exposes pilots to risk and is limited in endurance due to fuel constraints and pilot limitations. Even though it can fly at high altitudes in excess of 60,000 feet, it is still vulnerable to modern surface-to-air threats highlighted by the shoot down of an American pilot over the USSR and several losses over the Asian mainland in the late 1960s and early 1970s (CRS 2000, 2, 8). When considering the FY2001 DoD budget, the four oversight committees all expressed concern regarding U-2 procurement issues (CRS 2000, 12). Data from a comparable appropriations table in the CRS report indicated funding recommended by authorization and appropriation committees for U-2 programs for the 2001 budget was less than requested, while Global Hawk funding authorized was more than that requested (CRS 2000, 13). The Secretary of the Air Force at the time of the CRS report stated that he was considering reductions in the U-2 program and retirement of all U-2s by fiscal year 2011 (CRS 2000, 15). The U-2 has proven its worth but is now too outdated, difficult, and expensive to continue operations among a new breed of capabilities.

The other example is the F-15 series, which until the recent low rate production of the F/A-22, the E model was the most capable multimission fighter in the US Air Force arsenal. When envisioning the F-15 in flight, one thinks of an aerodynamic modern jet fighter. True, but even the F-15 is aging. Designed in the 1960s, the A and later C model was built in the early 1970s as a single-seat air superiority fighter, that first flew over thirty years ago. Research on adding an air-to-ground capability began in 1980, leading to production of the two-seat multimission E model, which first took flight nearly twenty years ago (Ciborski 2002). With global conflict and steady deployment, F-15 platforms are adding flight hours per year at a rate exceeding original lifespan projections. The F-15 service life including airframe, engine, and all component fatigue was originally based on a 4,000 flight-hour model. That has been extended to 8,000, the current baseline. Proposals for a 10,000 and 12,000 flight hour baseline are being considered. Figure 6 from the *McDonnell Douglas Aerospace Digest* displays service life timelines of A, C, E model F-15s for an 8,000 flight hour service life.

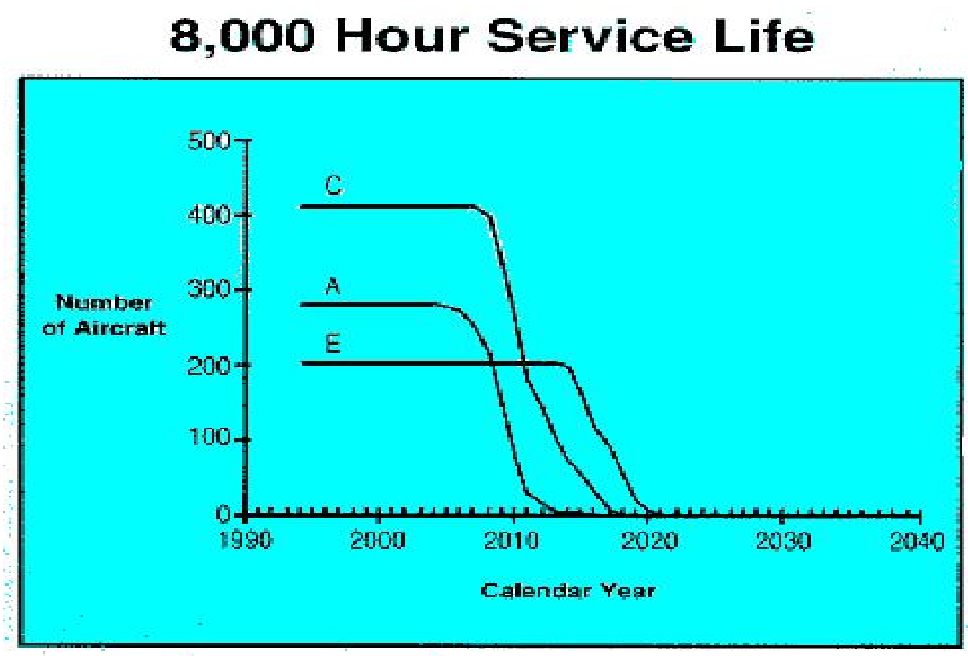

Figure 6. Projected F-15A, C, and E Model Service Life for 8,000 Flight Hours
Source: Rick Foster and Ron Mellier, "Built To Last," *McDonnell Douglas Aerospace Digest* 41, no. 2 (1994): 11.

In order to extend the service life, one of two things or both must happen. First, extend the amount of hours that can be flown per airframe. This may be possible with improved components and increased reliability. However, simply extending the hours permitted to fly does not come without cost. Reliability testing, research and development for improved components, and controlled risk are all considerations. A second possibility is refitting existing airframes with new replacement parts. The inner and outer wing panels, fuselages, and engines are the “big ticket” items when extending an airframes service life. Again, additional cost is associated. Extending service life is a multi-billion dollar venue when considering the current inventory of 475 F-15A-E models (Federation of American Scientists, 2005b).

The F-15C and E communities are also faced with the challenge of providing and maintaining pilots. During a Basic Fighter Maneuver Counter (BFMC) Detachment to Tyndall AFB, FL in late 2000, the commanding officer of the 95th Fighter Squadron indicated that the tactical fighter training squadron had seen an increased attrition rate in the recent past, which was having an effect on the numbers coming in the door. Not only was the training squadron seeing fewer student fighter pilots enter the program; it was seeing fewer succeed through training. Though rigorous and demanding, the F-15 pipeline should be highly sought. The phenomenon of not having students lined up at the door to achieve the “Fighter Pilot” title was a mystery to all instructors.

Overall, two trends seem evident, likely becoming constant themes for the future. These themes must be considered when planning tomorrow’s air force structure. First, given widespread media coverage and access to military operations as they occur, public opinion and society’s influence will be an increased factor on military decision making. This shows the American public the harsh realities of war reinforcing the public’s increasing sensitivity to loss of life. Second, budget constraints will drive the armed forces to be more cost effective in satisfying requirements. These trends favor an unmanned force if lower cost and sustained effectiveness can be proven. Work is currently underway to field unmanned systems across the spectrum from sea, air, and land, to space in the form of unmanned surface and undersea vehicles, unmanned ground vehicles, UAVs, and satellites and satellite delivery vehicles. It may be argued then that technology will fight and win the next conflicts by removing more and more of the human element or at least the danger to that human element throughout the battle space. Recent conflicts have proven that technology is welcomed but not a replacement for the human element. For now it is an enabler setting the conditions for the human element to achieve victory. Will this always be the case or will the future bring nearly virtual wars, fought largely from control centers instead of on the battlefield?

Unmanned Systems Status and Issues

Figure 7 presents a consolidated timeline of the services' ongoing and planned UAV programs, illustrating a snapshot of operational, developmental, and concept UAV programs. It has compiled information from individual service UAV roadmaps and presents programs led by each service, color-coded dark green (Marine Corps), black (Navy), light green (Army), and blue (Air Force). Programs that started as advanced concept technology demonstrators (ACTD) or advanced technology demonstrators are so indicated on the left end of their identification bar, with the leftmost bar indicating the conclusion of that program's demonstrator phase. The rightmost vertical bar indicates actual or projected initial operational capability.

Current operational UAV systems include MQ-1 Predator A, RQ-2 Pioneer, RQ-4 Global Hawk, RQ-5 Hunter, and RQ-7 Shadow 200. Combat experienced developmental UAVs including Dragon Eye, Neptune, and Force Protection Aerial Surveillance System (FPASS) will be discussed following operational UAVs.

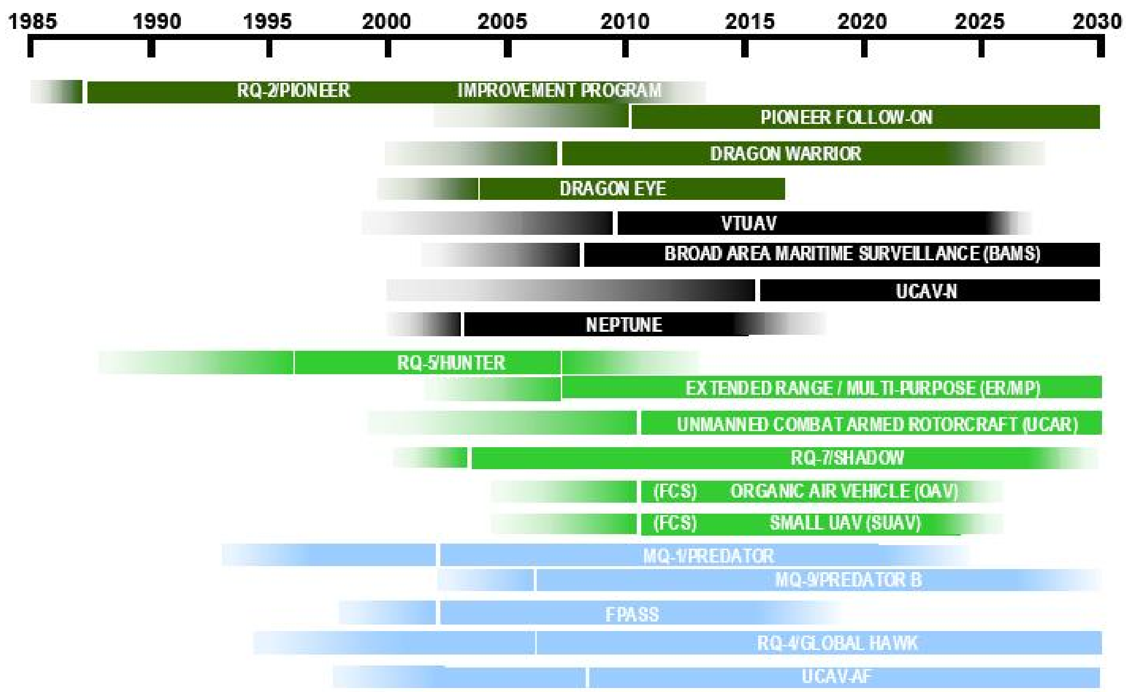

Figure 7. Timeline of Current and Planned DoD UAV Systems
Source: OSD, *UAV Roadmap 2002-2027* (Washington, DC: GPO, December 2002), fig. 2.0-1.

The Predator, first designated RQ-1 for reconnaissance (R), unmanned (Q), and the first of a series of purpose-built unmanned systems (1), began as an ACTD in 1994 transitioning to an Air Force program in 1997. Certain airframes were re-designated MQ-1 in 2002 following integration of a Multi-spectral targeting system and armament with AGM-114 Hellfire missiles, hence a multirole (M) system (USAF Fact Sheet 2001, 1-2). It functions like a conventional airplane during take off and landing from a 5,000 by 125 foot runway but while airborne, it flies with a gimbaled EO/IR sensor and a SAR giving it a day or night all weather reconnaissance capability. One pilot and two sensor operators positioned in a ground control station operate Predator using different data links either in line-of-site (LOS) (C-band) or beyond-LOS (Ku-band SATCOM) (OSD 2002, 6). It is equipped with a nose-mounted color camera, a day variable aperture television camera, an infrared camera, and a SAR capable of producing full-motion video and still-frame radar images that can be disseminated to multiple users. It is also equipped with an ARC-210 radio, an APX-100 IFF with Mode 4, an upgraded turbocharged 4-piston engine, and an anti ice system (USAF Fact Sheet 2001, 1-2). Nearly 29 feet long, Predator (see Figure 8) weighs 2,250 pounds, has just under a 50-foot wingspan, and can carry a payload of 450 pounds. Its combat ceiling is 25,000 feet with endurance of over 24 hours (OSD 2002, 6).

Predator evolved from the DARPA Amber program in 1984 and first flew in 1994 when it was originally designed as a medium-altitude, long-endurance, unmanned reconnaissance ACTD (OSD 2003, 6-7). As an ACTD, it underwent rapid RDT&E and fielding in actual conflicts ranging from Bosnia and Kosovo to Iraq, and Afghanistan. The MQ's current primary mission is interdiction and armed reconnaissance against critical, perishable targets and is a Joint Forces Air Component Command owned theater asset for support of the JFC (USAF Fact Sheet, 2001 1-2). During an interview with *Aviation Week's* David Fulghum in March 2003, David Cassidy, the President and CEO of the Predator's primary contractor, General Atomics said, "I want to see a Predator coming back here with MiG kills painted on its side; and this will happen soon." In the article "Predator's Progress," Fulghum stated Cassidy wants to move the company's aircraft into the air-to-air arena with a more formidable weapon than the Stinger that they currently carry. One Predator was nearly awarded a MiG kill painted on its side when it fired a Stinger missile at an Iraqi MiG-25. The MiG was too far away for returning fire to be effective and the Predator eventually perished to an incoming air-to-air missile. Cassidy commented, “They have been shot at a lot; now they’re shooting back.” He continued, “Payback is just around the corner when the larger Predator B model will be carrying AIM-9 Sidewinder and AIM-120 AMRAAM missiles” (Fulghum 2003, 2-3).

The one criticism that the Predator has taken is its reliability. Marc Herold of the Whittemore School of Business and Economics noted in an article he wrote that during operations in Afghanistan twelve percent of the Predator fleet had been lost. Of the twelve Predators deployed to Afghanistan, one-half of them crashed. At a cost of $4.5 million per unit, the price tag is adding up (Herold 2003, 3-5). However, he does not explain why they crashed or account for potential causal factors, like combat and unfavorable weather. One can also expect initial mishap rates higher that desired with rapid fielding, common among ACTDs. As more flights are conducted and improvements

Figure 8. General Atomics MQ-1 Predator A
Source: Department of the Air Force, *US Air Force Fact Sheet, RQ/MQ-1 Predator Unmanned Aerial Vehicle*. July 2001; [Website, USAF], available from www.af.mil/factsheet. Internet; accessed 16 October, 2004.

are made, mishap rates go down and reliability goes up. The reliability rate of Predator A and B as of February 2003, when the *UAV Reliability Study* was conducted, was 74 percent and 89 percent respectively corresponding to 43 mishaps per 100,000 flight hours for Predator A and 31 mishaps per 100,000 flight hours for Predator B (OSD 2003). Predator A and B have both improved beyond expectations with more flight hours accumulated in the last two years. “The US has had Predators airborne nearly continuously, twenty four hours a day, for over a year” Cassidy has said (Fulghum 2003, 3).

The RQ-2 Pioneer is a fairly old system with early operations beginning over twenty years ago. Originally the Navy purchased Pioneer in the mid 1980s to conduct naval gunfire support (NGFS) aboard its four Iowa-class battleships. The Marine Corps took delivery shortly thereafter, followed by the Army to fulfill an over the horizon reconnaissance, surveillance, and target acquisition (RSTA) capability (OSD 2003). Supporting the Marine expeditionary force out to a radius of 200 kilometers, the Marine Corps is currently the sole operator of Pioneer. All Marine Corps active systems are fully upgraded, integrating enhanced survivability modifications, upgraded flight control processors, global positioning system guidance, multiple redundant control link frequencies, new fuselages, redesigned engine shrouds for better cooling, updated engine components, auto-land systems, and digital air data systems (OSD 2003, 10-11). Like Predator, Pioneer is controlled via a LOS data link utilizing an EO/IR suite. It is however, limited in range to just over 100 miles with no SATCOM capability. Pioneer (see Figure 9) weighs only 450 pounds, is 14 feet long, has a 17-foot wingspan, a ceiling of 15,000 feet, and endurance of 5 hours (OSD 2002, 6-7). Pioneer’s reliability requirement set by the DoD is 84 percent but its actual reliability rating is 91 percent (OSD 2003, 13). Pioneer is limited only by its projected retirement date, which has already been extended. Currently it has been extended to operate until fiscal year 2009 or until a replacement is fielded.

Figure 9. RQ-2 Pioneer in Flight near Ground Control Station
Source: Department of the Navy, *United States Navy Fact File, RQ-2A Pioneer Unmanned Aerial Vehicle.* 2000; [Website, USN], available from www.chinfo.navy.mil/navpalib/factfile/aircraft/air-uav.html. Internet; accessed 26 April 2005.

Both RQ-5 Hunter and RQ-7 Shadow 200 are currently employed by the Army. Hunter was originally a joint Army, Navy, and Marine Corps short range UAV program that the Army intended to meet division and corps level requirements. Army ground commanders at the brigade level are primary users of the tactical UAV (TUAV) Shadow.

Hunter (see Figure 10), until the replacement future force UAV is developed and fielded, provides the maneuver commander with RSTA and battle damage assessment to a range of 300 kilometers and endurance of 12 hours with an expected growth to 500 kilometer range and 24-hour endurance (Department of the Army 2003, sec. 8-10, sec. 8-11). Hunter was initially plagued with a series of three crashes within three weeks, which called for a halt in full rate production in 1995. TRW, the Program Management Office and prime contractor, conducted extensive failure testing and analysis and determined several components that failed well before their projected fatigue failure rates. With the problems identified and fixed, Hunter returned to flight status and production three months later. After production continued, Hunter exceeded reliability requirements by eight percent. Sixty-two Hunters were built to deploy in sets of eight along with two ground control stations; mission planning, launch and recovery, and maintenance stations; and four remote video terminals at a cost of $1.2 million per aircraft and $24 million per complete system. It has supported combat operations as well as National Training Center exercises with multiple payloads including EO/IR, signals intelligence (SIGINT), chemical agent detection, and video data relay (OSD 2003, 14-17).

The Army employs the Shadow 200 (see Figure 11) system with three aircraft, two ground stations mounted on armored vehicles, and four remote video terminals to deliver near real-time video to maneuver commanders. Shadow currently has EO/IR sensors and will expand to accommodate all-weather SAR, moving target indicator, and SIGINT sensors (Department of the Army 2003, sec. 8-10, sec. 8-11). Shadow is a rail launched TUAV that is recovered via an arresting gear system. It has a 4-hour endurance and 50-kilometer range. Shadow is a highly reliable system with zero flight control failures during its initial 2,000 flight hours. The only failures were attributable to fuel leaks which have been fixed. Shadow entered full rate production in September 2002 (OSD 2003, 20). The 4th Infantry Division (ID), 2d ID, 3/2 ID Stryker Brigade Combat

Team (SBCT), and 1/25 ID (SBCT) currently employ Shadow and the Army plans to field it to forty one brigade level units by fiscal year 2009 (Department of the Army 2003, sec. 8-10, sec. 8-11). Shadow's only identified system vulnerability is sensitivity to environmental factors, a characteristic of many small UAVs (OSD 2003, 20).

Figure 10. TRW RQ-5 Hunter Rocket Assisted Takeoff
Source: UAV Forum, RQ-5 Hunter. 2005a, [Website, UAV Forum], available from www.uavforum.com/library/photo/hunter.htm. Internet; accessed 12 May 2005.

Figure 11. RQ-7 Shadow 200 and US Army Personnel/ Shadow and Launch Rail
Source: AAI, RQ-7 Shadow 200 TUAV. 2005, [Website, AAI Corp.], available from www.aaicorp.com/defense/uav/200.html. Internet; accessed 7 February 2005.

Developmental UAVs are on the rise. With the exception of the unmanned combat armed rotorcraft (UCAR), a combined DARPA and Army program cancelled in January of 2005, the DoD is proceeding with its other developmental UAV systems. Currently developmental UAV systems include the already tested and successful RQ-4 Global Hawk, the Navy BAMS program, rotorcrafts RQ-8 Fire Scout and Marine Corps Dragon Warrior, MQ-9 Predator B, mini-UAVs Dragon Eye, FPASS, and Neptune, and unmanned combat systems UCAV X-45 and UCAV-N X-46/ X-47. Developmental UAVs can be grouped into four categories: (1) ISR including high altitude, long-endurance, Global Hawk and BAMS; medium altitude long-endurance (MALE), "Hunter-Killer" Predator B; (2) unmanned rotorcraft, Fire Scout and Dragon Warrior; (3) mini-UAVs, Dragon Eye, FPASS, and Neptune; and (4) combat UCAVs, X-45 and X-47. The following section will highlight selected accomplishments or shortfalls of developmental UAVs.

The Global Hawk is perhaps the best example of a developmental system proving its worth in combat. Global Hawk, having proved itself in reliability testing, deployed before limited rate production was announced and has since been established as an operational platform within the Air Force's capabilities. Global Hawk (see Figure 12) is an ISR platform with the wingspan of a Boeing 737 that takes off and lands on a conventional runway. It has a thirty-two hour endurance employing EO/IR, SAR with moving target indicator, and imagery intelligence sensor suites. The Air Force plans a total fleet of fifty-one platforms, which will be flexible to accommodate improved sensor suites as technology matures. The Navy will likely use a modified Global Hawk platform with a maritime sensor suite to fulfill the bulk of its BAMS requirements. Ground stations in theater equipped with the common imagery processor will eventually be able to receive Global Hawk imagery directly. Currently, imagery is data linked to primary ground control stations and then disseminated via SATCOM links (OSD 2002, 8-9). Global Hawk is the modern age UAV success story and model program for others to emulate.

Figure 12. RQ-4 Global Hawk
Source: Government Accountability Office, *GAO-05-395T, Improved Strategic and Acquisition Planning Can Help Address Emerging Challenges* (Washington, DC: GPO, 9 March 2005), 4.

Mini-UAVs are rapidly becoming widely employed across the battlefield providing squads, platoons, and companies an organic RSTA capability. These systems are similar to remote control aircraft in the civilian world but pack a much greater responsibility and capability. Mini-UAVs vary in endurance from 45 minutes to 4 hours. Dragon Eye and FPASS are back-packable systems that weigh less than 10 pounds with controller, mission data computer, and platform while Neptune, also man-portable, is a maritime mini-UAV weighing 80 pounds. Minis have the capability of employing EO/IR, and low light color television sensors and cameras with real time feedback to the mission computer. The mission computer can be configured to operator preference, capable of displaying craft flight path superimposed over Falcon View, forward looking imagery, sensor data, and flight profile including altitude, attitude, climb or dive status, and remaining endurance. Mini-UAVs are inexpensive and continue to see improvements. One shortfall is the inability to operate in poor weather due both to flight characteristics of small craft and sensor capabilities (OSD 2002, 10-11).

The UCAVs X-45 and X-47 are the platforms within the combined DARPA, Navy, and Air Force joint combat systems project. These unmanned combat vehicles are being developed to prosecute suppression of enemy air defenses (SEAD), strike, and interdiction missions in the 2010 and beyond, high threat environment. The Air Force has budgeted for thirty-six X-45 systems for delivery by 2010 for early operational capability with advanced capabilities expanding in the future. The Navy is planning to test a shore-based catapult and arrested-landing capable Naval variant X-47 in late fiscal year 2006 with initial operating capability planned before 2015. The UCAV-N (Naval) acquisition cost goal is fifty percent of the F-35 and its operating cost goal is fifty percent of the F/A-18C/D (OSD 2002, 11-12). Both the X-45 and X-47 (see Figure 13) have been undergoing RDT&E and have successfully demonstrated fully autonomous ground taxi, takeoff, onboard systems analysis and repair, adaptive threat avoidance, ordnance delivery, battle damage assessment, recovery, and post flight (Defense Advanced Research Projects Agency 2005).

Figure 13. Northrop Grumman UCAV-N, X-47 Pegasus (left) and Boeing UCAV, X-45 at NASA's Dryden Facility, Edwards Air Force Base (right)
Source: Defense Advanced Research Projects Agency, X-45 System Gallery and X-47 System Gallery. 2005, [Website, DARPA], available from www.darpa.mil/j-ucas. Internet; accessed 14 March 2005.

DARPA, Service, and Contractor Partnerships

The J-UCAS program is the largest unmanned systems development ever undertaken by the DoD and arguably the most important program supporting the robust future of an unmanned flying force. The J-UCAS program is a joint DARPA, Air Force, and Navy effort to demonstrate the technical feasibility, military utility, and operational value for a networked system of high performance, weaponized unmanned air vehicles. The program is focused on effectively and affordably prosecuting twenty-first century combat missions, including suppression of enemy air defenses (SEAD), surveillance, and precision strike within the emerging global command and control architecture.

J-UCAS Program Office Director Dr. Mike Francis describes J-UCAS as follows "first and foremost, it is more than another unmanned air combat vehicle or even a collection of them. The vehicle portion of J-UCAS, which we call the UCAV, is merely the host around which the system is built. UCAVs are technologically advanced aircraft, to be sure, but the soul of J-UCAS lies in the command and control, sensor and weapons systems that enable their operation, individually and collectively . . . an affordable System of Systems . . . one that uses a Common Systems Architecture, Operating System, compatible air vehicles, and reduced support costs” (Francis 2004, 1-3).

Mr. Michael W. Wynne, USD (AT&L) (Acting), in June of 2003 also commented “J-UCAS is a key transformational program within the DoD’s portfolio. The capabilities offered by this family of systems can have profound implications on the Department’s future warfighting capability and force structure” (Northrop Grumman 2003).

Until recently this program was under direction and management of the DARPA. However, the Deputy Secretary of Defense made an oversight reassignment decision as part of a December 2004 budget-cut assigning the US Air Force as the lead agent. The reassignment may have been based on a reciprocal mind-set among recommendations to slash F-22 production and to terminate the C-130J. In the eyes of the DARPA leadership, who had made great strides in advancing the partnership program, this was not a wise move. Naval leadership, who saw the DARPA led program as a great way to head off service parochialism, agreed.

Regardless of the oversight agent, the project has continued with daily advancement and successes. Part of that success comes from the many contractor partnerships that are involved with the J-UCAS. Defense contractors are integral to advancing UAV technology. Not only are the major contractor partnerships important, but subcontractors are essential as well. The Defense Department, through statements, press releases, and guidance within the *UAV Roadmap 2002-2027*, has suggested areas of technology for the private sector to focus on and has tried to stimulate corporate investment in the expansion of the UAV industry.

There are several indicators that suggest that this DoD stimulation is having an effect. For example, new companies enter the market almost daily. Some companies are emerging in the field and other current technology companies are expanding to develop unmanned systems or subcomponents including Remote Services Ltd., AeroVironment Inc., Aurora Technologies, Inc., Schweitzer Engineering Laboratories, Inc., and Cyber Defense Systems, Inc. to mention just a few. As stated above, the UAV roadmap has identified key areas for development, which include incorporation of emerging technologies in platforms, propulsion systems, sensors, communication relays, weapons, and processors (OSD 2002, 61-64). Just using one of these areas, propulsion, as an example, the roadmap states that endurance is driven by propulsion (OSD 2002, 29). Continuing, the roadmap identifies two key propulsion metrics, which are specific fuel consumption for efficiency, and mass specific power for performance. It is projected that by 2025 at cruise conditions, specific fuel consumptions will be reduced from nearly 2 pounds per hour to less than .2 pounds per hour while mass specific power will increase from .1- .5 horse power per pound to .3- 8.5 horse power per pound, depending on propulsion method (OSD 2002, 29-30). What this means is power is projected to increase at the same time becoming more efficient, which translates into greater endurance. Figure 14 illustrates projected propulsion advances and is a benchmark of development for companies like Proton Energy Systems and Ballard Power Systems, who specialize in fuel cell technology; General Electric Company and Pratt and Whitney who have divisions specializing in turbine engines; and United Solar Systems Corp. and Astro Power Systems, who specialize in photovoltaics or solar cell technology.

	Now	2010	2015
Turbine Engine	Turbofan, turboprop, Integrated High Performance Turbine Engine Technology (IHPTET)	Versatile Affordable Advanced Turbine Engines (VAATE-1)	VAATE-II Note: VAATE ends in 2017
Hypersonics Scramjets	AF Single Engine Scramjet Demo, Mach 4-7 X-43C Multi-engine, Mach 5-7	Robust Scramjet: broader operating envelope and reusable applications (e.g. turbine-based combined cycles)	Hypersonic cruise missiles could be in use w/in operational commands. Prototype high Mach (8-10) air vehicles possible
Turboelectric Machinery	Integrated Drive Generator on Accessory Drive, Integrated Power Unit – F-22	No AMAD, Electric Propulsive Engine Controls, Vehicle Drag Reduction/Range Extension	Enabling electrical power for airborne directed energy weaponry
Rechargeable Batteries	Lead Acid, NiCd, in wide use Lithium Ion under development – (B-2 battery – 1st example)	Lithium Ion batteries in wide use (100-150 WH/kg)	Lithium polymer batteries in wide use (300-400 WH/kg)
Photovoltaics	Silicon based single crystal cells in rigid arrays	Flexible thin films Multi-junction devices – Germanium, Gallium based	Concentrator cells and modules technologies (lens, reflectors)
Fuel Cells	Prototypes in large UAVs – NASA ERAST (Helios)	Production PEM fuel cells (automobile industry driven) available for UAVs	Fuel cells size, weight reductions Improvements in reformers resulting in multi fuels use

Figure 14. Propulsion/ Power Technology Forecast
Source: Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, DC: GPO, December 2002), sec. 4.1.1.

Defense companies that finance or work with scientific and engineering teams to conduct experimentation and testing further highlights that the Defense Department's UAV stimulation of the private sector is effective. One example of this cooperation is the second annual UAV competition held last summer at the Webster Field Annex of the Naval Air Station, Patuxent River. Boeing, Northrop-Grumman, MicroPilot, the Johns Hopkins University Applied Physics Laboratory, ARINC Engineering Services and BAI Aerosystems in cooperation with Naval Air Systems Command sponsored the competition. The event was attended by UAV teams from Cornell University, North Carolina State, Virginia Commonwealth University, Santa Clara University, Polytechnic University of New York, Texas A&M, University of Texas at Arlington, Mississippi State, and Istanbul Technical University. Rick Greer of NAVAIR commented, “We expect to have more teams entering next years competition” (Jenkins 2004, 2). Objectives for each team entry required “an unmanned radio-controllable aircraft to be launched and flown manually, to transition to autonomous flight, navigate a specified course and use onboard payload sensors to locate and assess a series of man-made objects prior to returning to the launch point for landing” reported Jim Jenkins, editor for dcmilitary.com, who covered the competition (Jenkins 2004, 1-2). Other factors like endurance, reliability, and cost factored into teams final score. This is just one example of the relationship among the military, private industry, and experimentation teams.

Yet another reason the DoD believes its efforts to stimulate private sector advancement in the UAV field is paying off is demonstrated by defense contractors who have created UAV divisions. Boeing, for example, has established the Boeing Unmanned Systems Organization: In Transformation. Already renowned as a military aircraft provider, Boeing, through a partnership with the DoD, is working to meet the transformational needs of the military by focusing on one goal of becoming the preferred provider of integrated unmanned system solutions to military customers (Boeing 2005). The Unmanned Systems Organization of Boeing states they are much more than simply a platform provider; they are a dedicated team of technical experts with the experience and knowledge base to provide war fighters the means to accomplish their requests in a rapid and reliable manner. The Boeing Unmanned Systems organization strives to continue the relationship with its military customers built by and backed by the resources of the world's largest aerospace company.

<u>The UAV Roadmap, GAO Studies, and DSB Publication</u>

This section reviews three primary documents identifying the future direction and goals of the DoD UAV program and evaluates whether forecasted timelines toward those goals are on track or if adjustments need to be made. In March of 2003, the DoD revealed a plan to widely proliferate UAVs with the release of the *UAV Roadmap 2002-2027*. Dyke Weatherington, Deputy for the UAV Planning Task Force, Office of the Secretary of Defense, stated in a Pentagon press release 18 March 2003, “The roadmap provides those high priority investments necessary to move UAV capability to the mainstream. The potential value UAVs offer ranges across virtually every mission area and capability of interest to the DoD” (2003). UAVs have become a priority at the Pentagon, strongly supported by Defense Secretary Rumsfeld and pushed as a large component of military transformation. The Pentagon invested $3 billion to UAV projects in the 1990s and in the next five years plans to invest more than three times that, to a figure in the $10 billion range (Sample 2003, 1). Weatherington laid out the overarching goal and three specific purposes of the UAV Roadmap in a statement to the House Armed Services Committee shortly after its release in March 2003. In the Congressional statement, he said the overarching goal “is to define a clear direction to the services and agencies for a logical, systematic migration of mission capabilities to a whole new class of tools for the military toolbox, namely UAVs” (2003). The statement also identified three specific purposes for the UAV Roadmap. First, it provides options to senior decision makers in development of broad strategies that will define future DoD force structure. Those options include guidance on mission areas that can be significantly impacted by emerging UAV technologies, stressing the mission areas that can be supported both technologically and operationally. Second it defines investment priorities in the near term required to move UAV capabilities into mainstream use. With seemingly unlimited new UAV ideas and concepts that emerge daily, a systematic logical method to migrate UAV capabilities, which includes platforms and concepts, must be defined. This will benefit the warfighter and help organize the use of limited DoD resources. Third, the roadmap identifies high value areas of interest for industry partners and allies to guide independent investment and cooperation concerning future UAV efforts (Weatherington, 2003).

The roadmap has identified forty-nine goals for unmanned aviation that support the Defense Department's larger goals of "fielding transformational capabilities, establishing joint standards, and controlling costs" (OSD 2002, iv). A top ten list was developed from the forty-nine goals, which identify an Office of Primary Responsibility (OPR) to oversee accomplishments and adherence to deadlines for each of the top ten. The OPRs should consider these goals directive and will assess, revise, and report progress to the OSD the first quarter of each fiscal year. The top ten goals are as follows:

1. Develop and operationally assess for potential fielding a UCAV capable of performing several missions including SEAD/ Strike/ Electronic Attack; emphasize early fielding of an EA capability with growth to other missions. OPR: UCAV Joint Program Office (DARPA, USN, USAF). Due FY10.

2. Develop and demonstrate a tactical UAV-class aviation heavy fuel engine suitable for use in UAVs such as Shadow, Pioneer and -160. Growth potential to larger UAVs in the Predator class including Extended Range Multi-Purpose and LEWK, and Options for the small UAV class are also required. OPR: DARPA, USA, USN/USMC. Due: FY05/07

3. OSD, Joint Staff, and the services develop capability and/or capability-performance metrics to evaluate UAV program costs. Program managers should

provide Joint Staff and OSD written justification at Milestone B and C reviews when these metrics are exceeded, and provide appropriate management organizations with options for reducing costs to align them with these metrics when this occurs. OPR: OSD. Due: FY03.

4. Demonstrate High Definition Television (HDTV) capabilities with real- time precision targeting capability on a UAV. OPR: NIMA, USN, USAF. Due: FY05.

5. Migrate all tactical (Shadow 200) and above UAVs to Common Data Link (CDL)-compatible formats for line-of-sight (LOS) and beyond line-of-sight communication. OPR: USAF, USN, USA. Due: FY06.

6. Investigate low Reynolds Number aerodynamics with the focus on improving digital flight control systems optimized for small UAVs (i.e., those having Reynolds numbers less than 1 million). OPR: OSD, USA, USN, USAF. Due: FY06.

7. Define a standard UAV interface providing critical situational awareness data and precise location data supporting airspace integration. OPR: OSD, USJFCOM. Due: FY04.

8. Coordinate revising FAA Order 7610.4 to replace the requirement for using the Certificate of Authorization (COA) process for all UAVs with one for using the DD-175 form for qualifying UAVs. OPR: USAF. Due: FY04.

9. Define security measures required for positive control of weapons employment on weaponized UAVs. OPR: USAF. Due: FY08.

10. Decrease the annual mishap rate of larger model UAVs to less than 20 per 100,000 flight hours by FY09 and less than 15 per 100,000 flight hours by FY15. OPR: USAF, USN, USA. Due FY09/15 (OSD 2002, iv-v).

In addition to these goals, the roadmap provides: a historical background, update on current and experimental UAV programs, future requirements, goals regarding technologies and operations, and the way ahead through future direction. It is nearly a two hundred-page document that is as directive as it is informative. The roadmap is due for a revision sometime this year as several programs have been updated and technology has matured.

The Government Accounting Office (GAO) conducted several studies related to UAVs since the publication of the 2002 roadmap. The GAO is the audit, evaluation, and investigative arm of Congress with a mission to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the US people (GAO 2003, 24). The UAV related GAO reports are supportive and optimistic about the future of UAVs but at the same time identify shortcomings and recommend changes that may improve DoD UAV efforts. The UAV related GAO reports studied conduct and present certain aspects of the DoD's UAV plans to Congress. The latest report dated 9 March 2005 was conducted with the recognition that current generation UAVs in the midst of a military transformation are becoming increasingly vital. The GAO report titled *Improved Strategic and Acquisition Planning Can Help Address Emerging Challenges* identifies three items. First, it identifies current successes and emerging challenges; next it identifies the extent to which the DoD has developed a strategic plan and oversight body to manage its investment in UAVs; and finally it identifies lessons learned from the Accounting Office's earlier work that can be used to promote the efficient development, fielding, and operational use of UAVs (GAO 2005, 1).

The study found that certain mission success have been achieved, pointing out that fifty five percent of the Iraqi air defense time-critical targets identified in theater during March and April of 2003 were attributable to Global Hawk. Predator also performed medium altitude ISR and lethal strike missions in Iraq, Yemen, and Afghanistan. Smaller tactical UAVs like Raven and Pointer were employed throughout the Iraqi and Afghan theaters providing maneuver troops with ISR capabilities. For example, during a single mission, a team used a small tactical UAV to locate a target, cover the team's movements, target the enemy, and conduct battle damage assessment to determine if a follow on strike was needed (GAO 2005, 2, 6).

The bulk of the report discussed emerging challenges regarding UAVs and shortcomings of the UAV roadmap. Some of the emerging challenges pointed out by the GAO report were already known and being addressed by the DoD, but others are anticipated in this year's UAV roadmap revision. Shortfalls addressed interoperability issues and lack of poor weather operable systems. The report points out that services have generally been reluctant to adopt common mission management systems within similar types or classes of UAVs and that some UAVs are not fully interoperable with other UAVs, manned aircraft systems, or even ground forces. For example, ground forces may not have the capability to link to data provided by other services' UAVs. Services appear to be developing their own independent capabilities to satisfy their own needs. Poor weather operations are difficult for any human or equipment to work in; however, improved sensors are being developed to penetrate certain aspects of undesirable weather. On the other hand, it is not likely that UAVs will ever be able to operate in severe sandstorms, a downfall pointed out by the report (GAO, 2005, 3-8).

Shortfalls with the UAV roadmap itself include the lack of a strategic plan to guide investment, the lack of an established office with sufficient authority to implement the strategy, the lack of projected funding requirements and funding priorities for future UAV developments, and the lack of a mission statement describing evaluation of goals, revision measures, and the interrelationships of individual service plans and programs (GAO 2005, 6). The report does mention that the DoD is moving forward to correcting these issues. Establishment of the UAV Task Force may be the answer to overall oversight but it needs to be granted the authority to make budgetary decisions, develop metrics to evaluate goals, identify revision procedures, identify relationships among the services, and establish funding requirements and priorities (GAO 2005, 6-9). Currently the UAV Task Force does not have sufficient authority to accomplish those tasks. The 2005 UAV roadmap revision is anticipated to address these issues with inclusion of a mission statement, explanation of long-term goals and objectives, strategies to attain long-term goals and objectives, explanation of the relationship between long-term objectives and annual performance goals, identification of external factors that could affect achievement of goals and objectives, evaluation and revision criteria, a description of the relationship between similar programs, and information concerning funding needs and expenditures (GAO 2005, 8-9). Table 2 summarizes GAO findings of factors that either led to or limited the success of past UAV programs.

Table 2. Factors drawn from reviews of Past UAV Programs

Factors That Lead to or Limit Success

Lead to success	Limit success
Innovative process	Requirements that outstrip resources, including technology
Evolutionary approach	Rush to production
Management attention	Ambitious schedules
Simple requirements and fixed resources	Concurrent testing and production

Source: Government Accounting Office, *GAO-05-395T, Improved Strategic and Acquisition Planning Can Help Address Emerging Challenges* (Washington, DC: GPO, March 2005), 10.

The final portion of the report identified lessons from prior GAO work that may improve efficient development, fielding, and operational use of UAVs. The lessons are drawn from reviews of past UAV programs, identifying factors that have either led to successful or poor outcomes and are summarized in the preceding table.

As the GAO provides information and direction to Congress, the Defense Science Board (DSB), a Federal Advisory Committee, provides independent advice to the Secretary of Defense. The February 2004 *Defense Science Board Study on UAVs and UCAVs*, though a year old, is the best one-stop source on the current state of DoD UAV efforts and what needs to be done for UAVs to move into the mainstream. The 2004 DSB study concluded one overall recommendation, and several areas that require additional attention or significant change. The DSB Task Force found “the single most important recommendation is to accelerate the introduction of UAVs into the force structure” (DSB 2004, v). To achieve this recommendation the study suggested the Secretary accelerate UAV procurement and move systems into operational units at a faster pace.

The study identified two areas that require change to realize the potential of UAVs and UCAVs:

1. Requirements generated cost growth has killed many UAV programs in the past. OSD should require each UAV and UCAV program in system design and development or production stage to establish a well defined and well defended recurring unit production cost target per system. Deviation from that cost target will only occur by direction of the Service Secretary.

2. High mishap rates are frequently cited as a deterrent to moving widespread adoption of UAVs into the force structure. Over the last five decades, investments in aircraft reliability have been made to drive equipment failures to near zero. This implies that a serious reduction in UAV accident rates can, and should be, obtained with reasonable investments.

The study also identified the following five topics requiring further attention and new developments:

1. Address communication bandwidth constraints.
2. Consider approaches to common UAV mission management.
3. Work to allow UAVs unencumbered access to the National Airspace System (NAS) outside of restricted areas here in the United States and around the world.
4. Address selected technology issues.
5. Carefully investigate approaches that could allow UAVs to operate with more persistence (Israel and Nesbit 2004, 1-2).

The 2002 UAV roadmap set the foundation for addressing these five items by providing initial guidance. An anticipated 2005 roadmap release is said to expand on the above issues.

Tactical Control Network (TCN) Evaluation and Air Space Integration Plan

The Tactical Control Network (TCN) is a concept for C2 of a wide range of UAVs within a greater airspace environment. Widespread proliferation of UAVs requires a system of control and deconfliction. The Navy project being developed with aspirations of controlling a wide variety of UAVs, from multiple services and agencies, at all airspace altitudes, across a theater of operations is the Tactical Control System (TCS). The TCS modules that comprise a network can be configured in racks for ship-based operations, aerial control, land-based installations, and mobile tactical vehicles. TCS modules have been tested in all configurations. One testing example includes C2 of an unmanned rotorcraft, from launch through mission execution and recovery, all while airborne from a Navy P-3 Orion aircraft, proving the flexibility of the TCS. The system is being designed by Raytheon to integrate with existing C4I architectures and networks and has successfully controlled multiple UAV systems including Outrider, Predator, Pioneer, Eagle Eye, Hunter, and Fire Scout. The system has five levels of functionality with lower levels involving receipt of data and imagery. Intermediate levels provide C2 of the air vehicle and payload and the highest level provides complete UAV C2, payload control, imagery receipt, and the ability to takeoff and land. All levels of the TCS from lowest (I) to highest (V) are capable of processing and disseminating imagery to end-users. This allows the battlefield commander to receive, and in some cases depending on TCS level, direct the collection of imagery (Raytheon 2004, 1-2). Captain Daniel C. Duquette, head of the UAV office in the Navy's Air Warfare Division said in May 2004, "Integration is one of the major challenges still facing the military in its use of UAVs" (Roth 2004, 1-2). The goal of TCS is to provide interoperability and not only control and deconflict the UAVs, but also get valuable information to not only a single controller at one ground control station, but to multiple users across the battle space simultaneously at a rapid rate. Continuing Duquette noted, " With UAVs, we are at where we were with computers in the mid 1980s. We had many different types of computers, many different operating systems. We're trying to iron them out. The technology is there for the UAVs the military needs. The next piece is the formality of connecting them. We're moving quickly to make those pieces come together. It's happening, and it's pretty exciting" (Roth 2004, 1-2).

The Air Force has recently announced that it would like to be the DoD's sole executive agent for UAV oversight and control. The announcement has many implications and other services less than happy. Amidst a twenty five percent reduction of its fighter fleet and an expensive F-22 program, Air Force senior officials are attempting to reinvent the Air Force as the premiere organization for reconnaissance and intelligence gathering and expand its core missions beyond the “silk-scarf” force of manned aircraft (Aviation Week and Space Technology, 2005, 1-3). This would potentially give the Air Force substantial authority over UAV direction and heavy influence over funding during the Defense Department’s rapid expansion of its UAV fleet. The Air Force’s proposal argues that, “regulatory issues are best addressed by a single service” (Aviation Week and Space Technology 2005, 2). The proposal also states the Air Force is suited for centralized direction and oversight of all UAV programs including Army and Navy which seemed to be in line with the former Deputy Secretary of Defense, Paul Wolfowitz’s position. Wolfowitz was expected to make the final decision about the Air Force lead proposal, but it is still undecided due in part to a new deputy being announced by the president. The decision was expected two months after the former deputy’s decision to reverse the DARPA led plan for managing the J-UCAS. This occurred to the dismay of several who felt “DARPA leadership shielded the program from budget raids and parochial priorities” (Aviation Week and Space Technology 2005, 1-3). The then deputy’s reversal assigned the USAF as lead with the Navy and DARPA under Air Force oversight. The position argues that the Air Force is overseeing a method to bring a number of vendors and architects together utilizing one net, in other words, to expand and speed availability of network-centric capabilities. According to one senior aerospace executive with responsibilities in several UAV programs, “The Air Force is really charging hard on network-centric operations” (Aviation Week and Space Technology 2005, 1-3). The Air Force proposal lists several priorities in justifying a single service lead, in which it is poised to serve, the first of which is management of a combat network. Commonality in C2, administration of UAVs including standards for operating in airspace with manned aircraft, and managing communications and navigation systems round out the proposal priorities. The Air Force executive agent proposal is still in its early stages and came at the deputy's request to normalize UAV operations especially with success in recent conflicts (Aviation Week and Space Technology 2005, 3). As was the case when the Air Force was named executive agent for space, controversy and criticism abounds, especially from other services. This issue is yet another roadblock to wide proliferation of UAVs.

Despite the Deputy Secretary of Defense's JUCAS management position, as a result of past failures and the inability to make any rapid progress in fielding UAV systems, the Defense Department is reluctant to select one service as sole lead. Throughout time, two issues constantly recurred: funding unmanned over manned systems and the inability of a single service lead to manage a joint system to meet differing service needs (CRS 2003, 8-10). Over the years, Congress and the Defense Department have tried several ways to manage UAV programs. Oversight often was imbedded in a directorate of the OSD with management residing within military services for individual programs. When this system did not produce adequate results, a JPO was established. Congress was a critic of the JPO stating, "Remarkably little progress has been registered. . . . The Secretary of Defense should undertake a comprehensive review of the JPO" (U. S. Congress 2003, 635). To more effectively manage UAV efforts, the JPO was replaced by the Defense Airborne Reconnaissance Office only to be disbanded amid further Congressional criticism. Since termination of the Defense Airborne Reconnaissance Office in 1998, there has been no single procurement focal point to manage DoD UAV efforts (CRS 2003, 9). A JPO has been reestablished with cooperation of DARPA, Navy, and the Air Force but even this JPO has been scrutinized. To stabilize and focus programs, the DoD UAV Planning Task Force was established to steer UAV efforts and progress. Service and agency direction, responsibility, and oversight was established in the latest DoD UAV roadmap and is said to be refined in the next revision which should be released in 2005. Currently, the DoD wishes to stimulate progress in the field by competition. Not competition with redundant RDT&E, but rather in the advancement of technology, to rapidly add a new series of weapons systems to the military's arsenal. Although competition is encouraged with the intent of advancing and rapidly fielding UAV systems, one of the criticisms lies in the absence of overall control from a network standpoint. The 2005 UAV roadmap, although not yet released, is said to address this issue.

Related to the control network, the OSD has conducted an unmanned aviation airspace integration plan, which was released by the USD (AT&L) on 23 November 2004. The plan establishes top-level timelines and program milestones to achieve safe, routine use of the National Airspace System (NAS) by DoD UAVs. The focus is on leveraging the existing NAS procedures for manned flight operations to accommodate unmanned systems and not creating a whole new set of rules and regulations specific to UAVs. In order to achieve integration into the NAS, the OSD has identified six key regulatory and technology issues which must be addressed to include air traffic; airworthiness certification; aircrew qualification; see-and-avoid; C2, and communications; and reliability. The airspace integration plan is based on continual efforts between the OSD and the FAA. The plan covers these six issues in depth, enforcing strict standards and metrics drawn largely from historical data from existing civil, military, and commercial aviation publications. The approach does not intend to create new initiatives that will limit the services' right to self certify manned or unmanned aircraft and aircrews, nor place constraints on existing air traffic control procedures and practices. It does intend to "conform rather than create" by interpreting Title 14 Code of Federal Regulations (formerly know as Federal Aviation Regulations or FARs) to also cover unmanned aviation as much as possible. The goal being transparent flight operations within the NAS regardless of manned or unmanned (OSD 2004, 2). For example, the term and responsibility "see and avoid" may flex to "sense and avoid" to include the UAV and incorporate an improved collision avoidance system. As with existing Code of Federal Regulations, the section dealing with emergency procedures will be expanded to include lost link and temporary loss of air traffic control communications with procedures necessary to accommodate UAVs. This is another example of building upon existing publications (OSD 2004, 19, 31).

The airspace integration plan has been developed in response to the reality of increased UAV usage, not only within restricted military airspace, but also throughout the national airspace as UAVs continue to mature. Figure 15 illustrates some of the key milestones, goals, and timelines for airspace integration.

The plan is progressive in nature with a short-term milestone to no longer distinguish between manned and unmanned flight by 2015. The idea being, simply file and fly, the same day, to and from any approved UAV operable airfield (OSD 2004, 47).

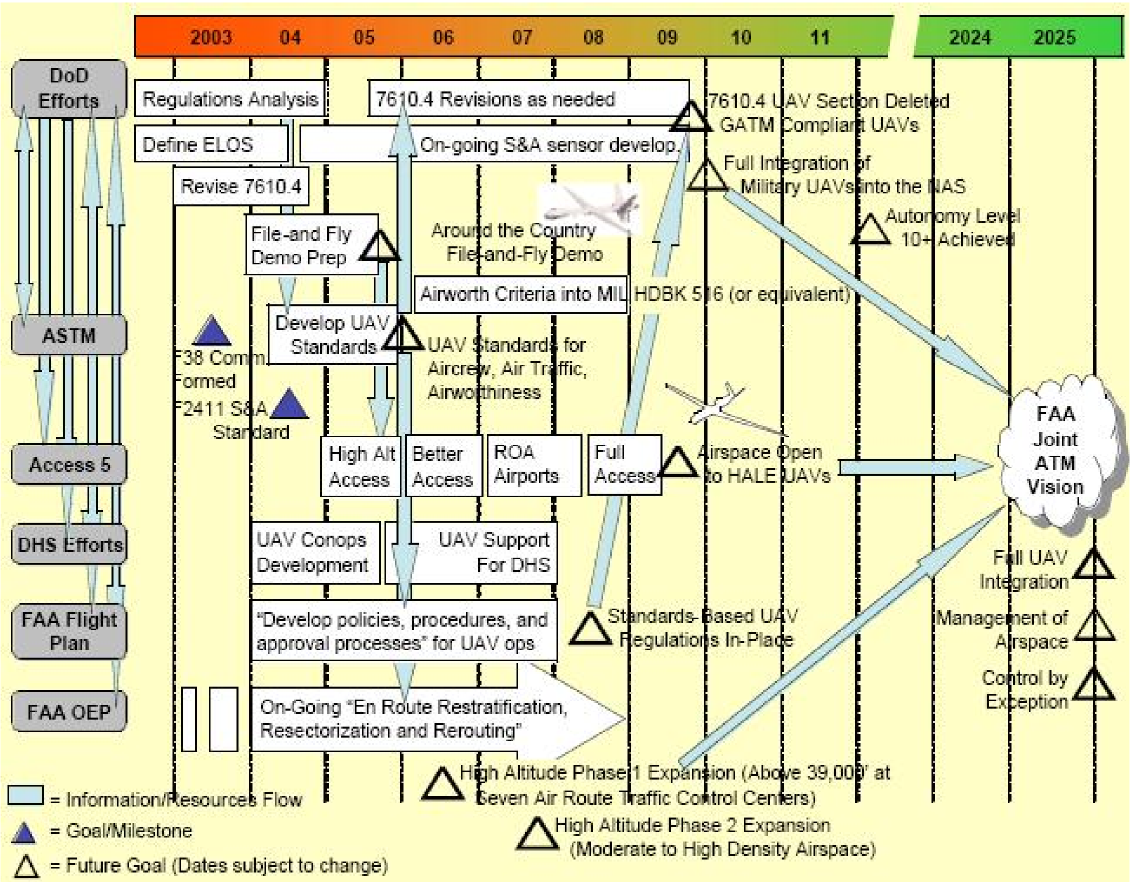

Figure 15. Remotely Operated Aircraft Airspace Integration Plan
Source: Office of the Secretary of Defense, *Airspace Integration Plan for Unmanned Aviation* (Washington, DC: GPO, November 2004), sec. 6.0.

Chapter 2 Recap

Industry

Worldwide interest in UAVs continues to expand and with the exception of passenger travel, will grow faster than all other segments of the aerospace market. There is a rigorous pace of expansion based largely on recent proven successes. There are literally thousands of private companies involved in the field directly or indirectly with avionics, sensors, weapons, and propulsion systems. Figure 16 indicates revenues vs.

employees by company. While viewing the figure, by simply looking at the vertical axis alone, one can identify that the UAV industry today is massive and continues to grow.

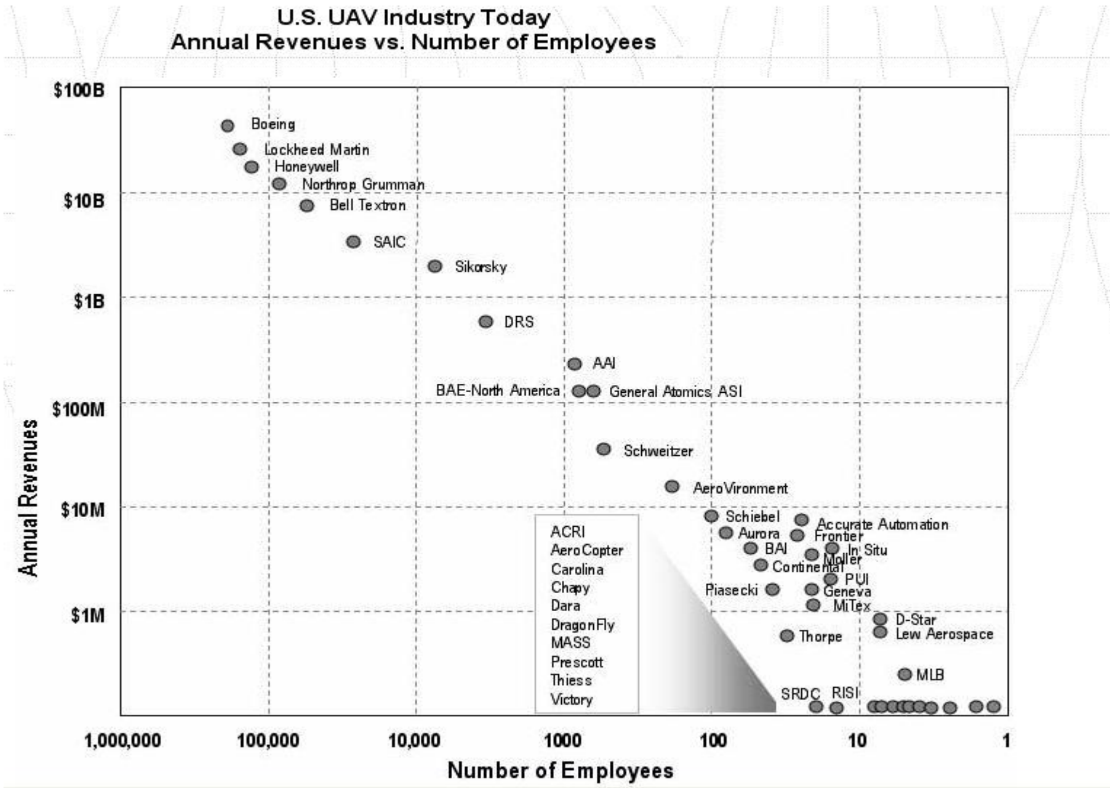

Figure 16. US UAV Industry Today [2004]
Source: UAV Forum, US UAV Industry Today. 2005b, [Website, UAV Forum], available from www. uavforum.com/vendors/vendgraph.htm. Internet; accessed 20 February 2005.

Interoperability and Service Parochialism

Services are struggling to find common ground when considering vastly different roles. Direction from DoD helps by identifying program leads, defining roles, and mandating compliance timelines. The UAV Task Force and the UAV roadmap are great sources of support and guidance. Congress has issues with the Army assessment of its

FCS requirements. Both the *ATR* and the Army's UAV Directorates help by continually revising requirements and future capabilities. The Navy and Marine Corps have issues defining future requirements especially with manned and unmanned assets that compete for funding under the larger struggle to fund current fleet operations and future ships in ten years, twenty years, thirty years and beyond. The DoD is advocating a smaller, quicker fleet to tackle littoral operations. This view supports current and short-term (ten years out) operations. Defense analysts caution this fleet structure, especially in the wake of a growing Chinese Blue Water Navy, that is projected to have more submarines than the US fleet by 2015 and a potential fleet of aircraft carriers as well. In addition to Navy efforts, the Marines have looked at tactical requirements on the battlefield and are proceeding with Dragon Eye. The *NTR* and Naval UAV roadmaps help to both define future requirements and current operations requirements by addressing key budgetary decisions that need to be made now. The Air Force has recently adopted a projected UAV plan to assume oversight of all UAV efforts, a move that has stirred quite a controversy among the other services. Meanwhile the Air Force continues to improve Predator and Global Hawk and is working on FPASS.

Establishment of UAV program directorates, battlelabs, and partnerships have improved UAV efforts among the services. To ease tension and promote UAV futures, the services depend on the guidance from the DoD to field the requirements that the war fighters of each service are asking for and need.

Joint Force Direction

The *TPG*, service transformation roadmaps, OFT, and JFCOM all support implementing the capabilities allowing the US Armed Forces to operate more effectively to ensure national defense and the other priorities of the president. A large factor in the effectiveness of future US armed forces is operations in the joint realm, which means the services' must plan for interoperability now. "If you're not interoperable, you're not on the net, not contributing, not benefiting, not part of the information age" (OFT 2003a, 23).

DoD Direction

Capabilities alone without support will not be implemented. Capabilities that can be applied to valid requirements that provide an advantage to what is currently employed will gain attention and high priority. Direction and support for UAV futures is very strong from the Secretary of Defense and within the Defense Department. This support stems from a viewpoint of a smaller, more agile and responsive force that incorporates the best possible use of technology; recent UAV successes; war fighter needs and requests for more UAVs; and the ability to integrate them into the joint force in order to fight more effectively in the future.

Senior Service Leadership Direction

In the absence of direct interviews, excerpts and quotes from current articles, strategy publications, and vision were used to form the position of key leaders regarding their views on UAVs. Their positions not only reflect their viewpoint but that of National Command Authority and the operational war fighters. Despite an optimistic outlook for the potential of an unmanned flying force, senior leaders are realists. They realize that it will take time, effort, and money. And that is why it is important to make the difficult decisions now to balance investment. That means harmonizing investment in maintaining current service capabilities, while investing in the capabilities of the future, ensuring the defense of our nation and support of allies, home and abroad. Senior leaders also know that manned aviation mishap rates have been on the decline due to implementation of standard operating procedures, safety regulations, currency requirements, and more reliable aircraft. They also know that even with current low mishap rates that almost all of modern mishaps are attributable to human error in some way. With that in mind they also recognize that it will be difficult to overcome the mind-set of the pilot; to convince pilots that a machine can outthink and perform them; to convince a human passenger that the coast is clear, the most capable pilot, a computer, is at the controls. Leadership recognizes that some mission areas simply do not favor UAVs.

Roadblocks and Limitations

One of the largest limitations is basically the assumption that technology will continue to evolve. Though evolution of technology cannot be disputed, the rate it will evolve is speculative. All technological ventures involving dependence on future grown and development are subject to the uncertain future. Many past DoD programs and UAVs in particular were cancelled either because of a lack of funding or because technology simply did not catch up with the concept. Technological deficiencies are many. A reliable network, bandwidth, survivability, stealth, weapons, sensors, and many more can be included. This is not to say scientific laboratories, defense contractors, and service teams are not addressing these concerns. It is to say that the uncertain future is a concern, especially when today's UAV plans depend on future technologies. The GAO identified that a factor that limits UAV development is overly ambitious schedules, that is to say, not properly forecasting the future and marrying development with maturing technology (GAO 2004, 13).

The way in which a program is managed and funded can often times lead to eventual fielding or cancellation altogether. Throughout the history of UAVs, the DoD has struggled with their oversight. At times, working groups showed little progress, at others, service leads showed little progress. At still other times, a project appeared to be on the right track to fielding but either a lack of funding or program mismanagement led to cancellation. History has shown that traditional procurement systems are not adequate to rapidly RDT&E and field certain capabilities. When dealing with cutting edge technologies, traditional procurement usually leads to programs that are behind timeline and over budget. The DoD is trying to hedge this problem with innovative procurement and managerial systems like advanced technology demonstrators and ACTDs.

Congress ultimately decides budgetary decisions. Despite a push from the Secretary of Defense and an increased trend in authorized funding, UAV funding remains at relatively low levels within the entire DoD budget. Congress wants to see results from the billions of dollars that it approves. Congress has seen UAV systems acquisition processes suffer “mission creep” as was the case with Global Hawk. Design and capabilities requirements continued to grow and change forcing contractors to make modifications to propulsion systems, wings, and other structural parts which increased its per unit cost by fifty percent in five years (GAO 2004, p14). Congress is not politically reluctant to wide proliferation but it does demand returns on its investment.

The lack of service unity and cooperation in the day and age of joint operations still exists, although to a decreased extent. Each services transformation roadmap is much more than a vision; they are benchmarks for measuring funding requests for the future. The future capabilities identified within must also satisfy joint requirements. Therefore, the services are obligated to identify individual needs that enhance joint operations. Even with a trend toward increased interoperability, services are still competing for precious resources and compete to provide unique capabilities. In the past, rather than pooling resources for unified UAV development, parallel programs led by multiple services, often resulted in both programs failing. By identifying program leads, the *UAV Roadmap 2002-2027* aims at unifying efforts such that joint UAV programs will succeed.

The tide seems to be changing when considering the “pro pilot bias” or the “white scarf syndrome.” There seems to be an aviator culture averse to transition away from their area of expertise toward an unproven unmanned technology. If you ask an Air Force Space Officer or Personnel Officer if a completely unmanned air force is possible, they would tell you “no way, the leadership, the fighter pilots, will never let it happen.” Being around the aviation community, one can begin to see that the reluctance of senior aviators to embrace UAVs is based more on skepticism toward their effectiveness and not necessarily pilot pride. Gaining the confidence and cooperation of aviators and employing them in the control van rather than the cockpit is definitely an obstacle to overcome.

Along with winning the hearts and minds of the aviation community, competition for funding from other weapon systems is perhaps the largest obstacle. An enabler to getting the funds is proving cost effectiveness, which is another problem in itself. UAVs have not had the best track record when it comes to mishaps. The mishap rates will surely decline over time and have with the systems that are currently in place, as did manned rates as more flight hours were flown and safety policies exercised. Lack luster mishap rates still do not help when asking for more money for new programs. The balance of continuing current funding while looking to the future has been difficult for the military and will never change. It affects UAVs just as it affects manned aircraft or any other capability. The fact is, it is a reality and must be planned for. UAVs will be in competition for the same dollars that are going to programs like the F/A-22, and developmental F-35.

Wrap-up and Transition to the 2025 Air Forces Proposal

What does this all mean? Has the research presented any evidence suggesting a completely unmanned flying force? The research produced evidence of ever-increasing UAV presence but not of complete unmanned aviation. There are certain missions, such as reconnaissance and precision strike that are more likely than other missions, like air interdiction and close air support, that will become completely unmanned in the very near future. The majority of evidence collected favors an integrated manned and unmanned flying force at least through the year 2025. The timeline projections within the *UAV Roadmap 2002-2027* forecast out to 2030. Beyond 2030, a completely unmanned flying force is technologically possible; however, several obstacles will likely preclude that from happening. Further, the position of current leadership does not support a completely unmanned force, rather a position of full integration is found. Current forecasts and strategy suggest that the technology will be present, but the mind-set will not, at least through the year 2025. It will be difficult to win the hearts and minds of the aviation community, imploring them to hang up the flight gear and man the ground control stations. It will also be difficult to assure passengers to sit back and enjoy the ride while the most able pilot, a computer, is at the controls. Figure 17 provides an idea of the timeline for transitioning to UAVs from the existing manned platforms. Because the transition has already begun, not seen are the ISR roles that the U-2 and Global Hawk are conducting today. Some project that the U-2 is capable and will continue to operate with its current upgrades and inventory, providing ISR well into the future, for at least another thirty-five years. Others forecast the U-2 retiring by fiscal year 2011.

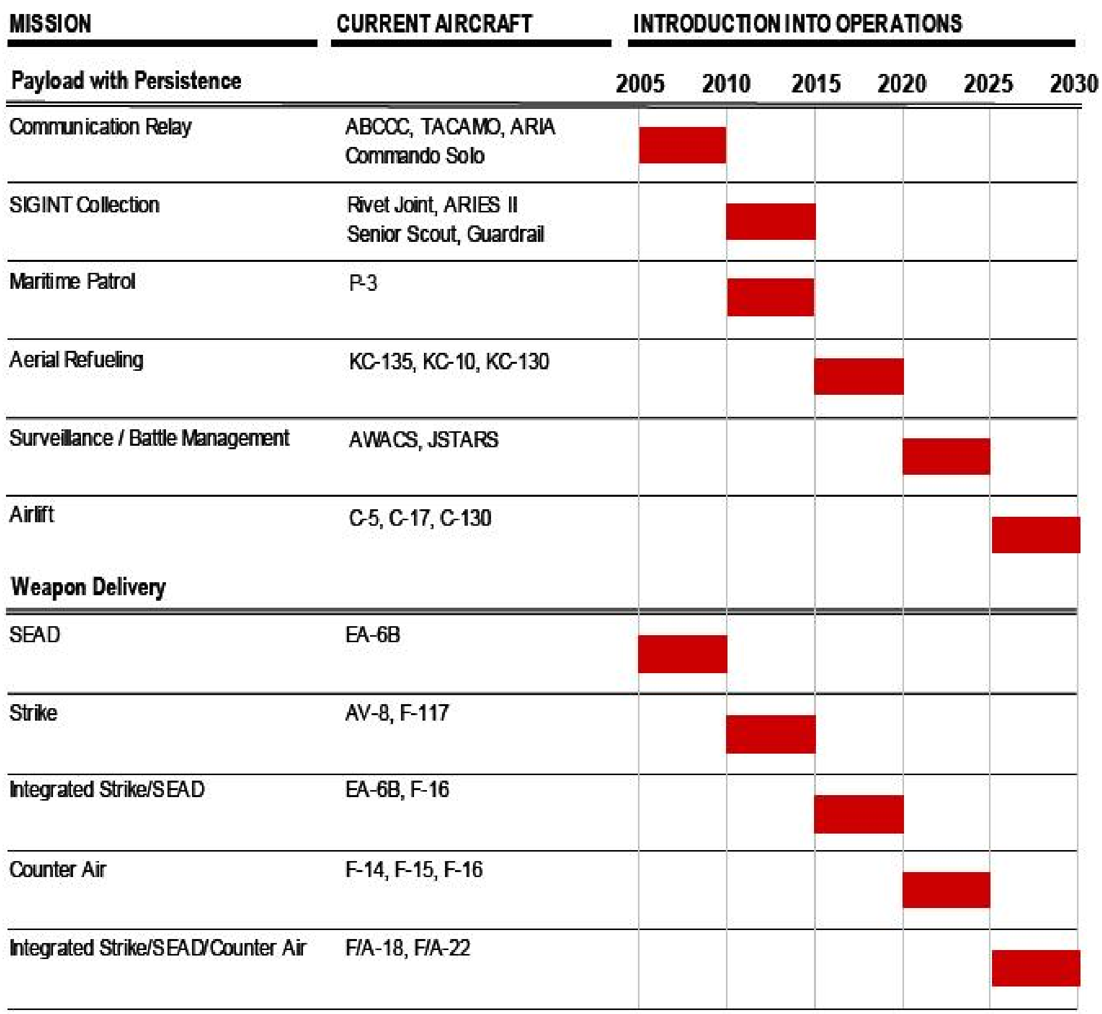

Figure 17. Forecast Transition to UAV from Current Aircraft by Mission
Source: OSD, *UAV Roadmap 2002-2027* (Washington, DC: GPO, December 2002), 58.

CHAPTER 5

PROPOSITION, FURTHUR ACTION, CONCLUSION

> Leadership is the capacity to translate vision into reality (1874).
>
> Benjamin Disraeli, Former British Prime Minister

> The Air Force will exploit the technological promise of unmanned aerial vehicles and explore their potential uses over the full range of combat missions (1996).
>
> *Global Engagement: A Vision of the 21st Century Air Force*

At the onset of this project, the overwhelming volume of success stories concerning UAV achievements and technology breakthroughs strongly suggested that it would not be long before man and machine integrate in some regards and separate further in others. Morals and ethics impact important decisions today and will continue in the future. Decisions that affect humanity, for example, whether to entrust computers with the responsibilities of making life and death decisions in the form of targeting, are affecting decision makers now about the future. Initially the research looked to prove that the DoD was progressing in the direction of phasing out current aircraft and replacing them with UAVs. Though there is evidence to support this transition, the preponderance of evidence supports the continued use of manned systems. In fact, the Defense Department's current stance is one of fully integrated manned and unmanned flight operations.

The idea of creating a proposed 2025 military flying force was largely based on the research leading toward a completely unmanned future flying force. However, the research does not support such a claim. The future of US military aviation, at least in the next twenty years, will still include manned aviation and probably for quite some time after 2025. This is not to say that UAVs will fall by the wayside never seeing prominence. The research yields neither a replacement or augmentation answer to the thesis question. Instead, UAVs will share roles, missions, and the airspace right along side manned formations. A complete replacement position by 2025 and probably well beyond is simply not possible for several reasons. Technology is projected to evolve and mature by 2025, such that unmanned platforms could perform all the missions that current manned aircraft perform but a completely unmanned air force that conducts complex air operations in all aspects is not possible. Having the technological capability of a completely unmanned air force will never eliminate the requirement of the human element.

In fact, regardless of complete unmanned or integrated future flight operations, manning the unmanned force is a dire concern. In the *Aerospace Power Journal*, spring 2005, Major James Hoffman, Chief of UAV Reconnaissance Operations, 609th Combat Operations Squadron, Shaw Air Force Base, South Carolina, and Mr. Charles Kamps, Professor of War Gaming at Air Command and Staff College, Maxwell Air Force Base, Alabama, project over 400 major system UAV pilots will be required by 2012. However, with only about sixty currently, a struggle to find even twenty UAV pilot volunteers, and no established program to train and maintain them, a serious examination must be conducted. This is a definite red flag for future UAV proliferation and an issue that must be addressed if UAVs are to continue to be employed at an increased rate (Hoffman and Kamps 2005, 1-5). The article they wrote is a good beginning, recommending possible solutions to the manning issue but further study must be conducted. Within this area of study, analysis should include the qualifications required for UAV pilots. These questions come to mind and should be considered. Must UAV pilots be winged aviators that transition to unmanned platforms? Should a completely unmanned pilot training program and flight school be established? Do UAV operators need to be pilots at all or even officers? As UAVs become more autonomous and do not require operators to control terminal (takeoff and landing) or in-flight phases, might payload operators, data analysts, and technicians make more sense than hands on stick and throttle pilots?

The foremost reason UAVs will not completely replace manned aviation by 2025 is not deficient technology, but rather the intent and direction of senior leaders. The current leadership realizes that certain missions do not favor, at least for the moment, using unmanned vice manned platforms. They also, by analyzing past failures, recognize that overly ambitious goals and schedules will likely result in failure and ultimate cancellation of programs at a very high cost. A cost they simply cannot afford in today's budget. They must forecast challenging yet realistic and achievable objectives and timelines that support future requirements. Leaders must have vision and establish program management, control measures, and evaluation criteria. They must also ensure that their vision accomplishes their intent. This involves continual assessment of program effectiveness, budget, and timeline. Current leaders recognize that UAVs and related technologies can greatly enhance military capabilities but they balance fielding unmanned aircraft with sound judgment in their application. UAVs have their place in the future force but for the foreseeable future, they will integrate within the airspace in, around, and next to conventional aviation.

Another reason that UAVs will not replace piloted aircraft by 2025 lies in human resistance. Since the inception of the military aircraft, the mishap rate per flight hours has continued to drop dramatically. Yet today, a majority of military aviation class Alpha mishaps are contributable to human error in some way. This lends favor to the advocates of removing the pilot. This still leaves room for error and potential mishap; after all, a fully autonomous UAV still requires human intervention in the form of flight, traffic control, ground, and maintenance personnel. UAVs must also prove a near zero mishap rate before any missions would be considered involving transport, CSAR, or medical evacuation of personnel. Assuring passengers that the most qualified and reliable pilot, a computer, is at the controls, in this time or even in twenty years does not sound like a reasonable proposition. Maturing technology and a cultural shift in the future may change that proposition to not only reasonable but also completely normal and acceptable.

Precision targeting has been conducted with UAVs, however fratricide and immediate threat to friendly troops and civilians has been minimal if at all. Missions that involve unmanned platforms delivering ordnance in close proximity to friendly troops or civilians will incur resistance but is more likely to be accepted sooner than unmanned transport. Again, reliability must be proven and ground commanders must be able to influence ordnance delivery through direct link to the unmanned delivery platform. Without direct interface and proven reliability, unmanned close air support missions will be met with resistance.

UAVs will also not replace manned aviation in 2025 because weapon systems compete for funding and a large portion of funding has already been appropriated for several conventional military aviation programs. Some programs including the F/A-18E/F and G, F/A-22, and V-22, not to mention a host of upgrades for other current manned aircraft, extend projected service lives to well beyond 2025.

The last reason a completely unmanned flying force will not be seen in 2025 is current functional and developmental UAV systems and the network to control them are not projected to be fully autonomous and capable by 2025. Advances are made daily, however, as past failures have shown, programs that are over budget, behind timeline, overly optimistic, with unrealistic goals and mismanagement rarely succeed. The UAV Task Force is vigorously striving to remedy past failures and continues to improve on initial guidance and direction for UAV futures. The 2005 UAV roadmap update, for example, is said to update requirements and address several shortcomings identified by Congressional and Defense Department analysts and advisory groups.

The research has established that complete replacement will not happen, at least in 2025. How about augmentation? An augmentation position suggests that UAVs will remain supportive to other assets (manned aircraft), and never achieve commonality and level or higher priority. Augmentation implies that UAVs will never be the supported, or main capability, with manned aircraft supporting their missions. It implies that UAVs will not be perceived as platforms that are as or more capable than their manned counterparts, that they will not be favored or the platforms of choice.

Instead of replacement or augmentation, UAVs in 2025 will be commonplace, executing missions fully integrated into the force. Each time that aviation is mentioned in strategic, doctrinal, and operations documents, unmanned will appear right before or after manned as the *AFTFP* already exhibits. Pilots of manned and unmanned platforms will brief and debrief via teleconference from the US or forward operating ready rooms and ground control stations. They will fly their aircraft from and to operating bases around the globe, across borders, across oceans, and through international airspace fully integrated with manned and unmanned civil, military, and commercial, traffic. Following a mission in the western pacific, the Strike Lead, flying a joint strike fighter and the only pilot to have actually flown onboard his aircraft, after rendezvousing with and directing his two divisions of unmanned strike aircraft recovers at Al Jabber Air Field, Kuwait. Two Pegasus UCAV pilots each having controlled 4 UCAVs will return to their staterooms onboard USS Ronald Reagan. Meanwhile, a Global Hawk pilot will return to her home in South Carolina, and the SEAD lead, an X-45 UCAV pilot will return to his home in Virginia having never seen his three aircraft, for they were recovered and turned around by ground personnel at Al Udeid Air Base, Qatar. One Pegasus division, having held its ordnance during the first mission, remains airborne allowing a ground control crew swap. The oncoming Pegasus division pilot, having already briefed, proceeds to rendezvous with another joint strike fighter for execution of a follow-on strike. The Global Hawk meanwhile, having already been on station for nine hours returns to Bealle Air Force Base, California after flying a thirty-two hour flight. The flight debrief does not take hours as has been required in the past. With exception of a face-to-face between the Strike Lead and the intelligence center, the debrief is already complete via real time data links within the UAV control network. Multi-spectral imagery has been gathered and analyzed assessing battle damage assessment. Seven of eight time critical targets are destroyed and a follow-on strike is already in progress.

It is speculative to identify exactness of an uncertain future, but despite the research leaning away from completely unmanned air forces, the 2025 US military flying forces can be forecast fairly accurately. A large majority of the manned force will be reduced due to airframe fatigue, component failures, and life expectancies, but new manned aircraft, upgrades, and new models will still fly well into the future. The 2025 Air Forces will still likely see fighter and attack jets like the F-15E Strike Eagles, F/A-18 E/F and G Super Hornets and Growlers, and F/A-22 Raptors. It will likely see transport aircraft like the C-130J Hercules and C-17 Globemasters, strategic bombers including the B-1B Lancer, and the B-2 Block 30 Spirit. It will likely see MH-60G Pavehawks, AH-64D Apaches, and OH-58D Kiowa Warriors. But it will also likely see MQ-9 Predator Bs, RQ-4 Global Hawks, UCAV X-45s and X-47s, and a host of man portable and tactical UAVs. The functions and roles that have already been employed like ISR, and precision targeting are certainly likely. The UAV Roadmap has identified a forecast for implementing UAV capabilities across the operational functions of airpower including priorities for fielding as was seen in Figure 17. The exact air forces composition is complex and continually changing, as can be observed with the cancellation of the Comanche program, scaled back production of the F/A-22, and an uncertain future for the joint strike fighter. Active and developmental unmanned systems are just as volatile. What is known is the 2025 air forces will be comprised of an integrated mix of manned and unmanned capabilities based on DoD civilian and military direction, defense projections, status of experimentation, fielding of current systems, and potential for fielding of developmental systems.

This study was constrained by the cap of a twenty-year future. Much progress is required to achieve ubiquitous and fully integrated operations in that time, but the future far outstretches the next twenty years. Several recommendations for further study and action were identified through this work. First, in order for the Defense Department to achieve the goals it has set forth, primary oversight and direction must be revisited. Of the studies that have been conducted regarding the *UAV Roadmap 2002-2027*, shortcomings in management, oversight, and budgeting priority were identified. The anticipated roadmap revision is a document to keep an eye on for future UAV efforts.

As UAVs become more widely integrated, manning the unmanned force will become an increased factor. Currently the armed forces are falling short of pilot goals, let alone unmanned pilot requirements. A careful study of this issue must be conducted, sooner rather than later. The longer this issue is not resolved, the worse the problem will become.

Airspace deconfliction is another issue that requires a watchful eye. The UNITE alliance in conjunction with the National Aeronautics and Space Administration, the FAA, and the DoD have made progress in this area. Follow up on the progression of the airspace integration plan is a must.

In the information age, everything seems to be more reliant on speed and accuracy. With that comes the reliance on wireless and networked technology. Under the constraints of wireless and network technologies, UAV command and control requirements still demand timeliness and precision. The survivability of several systems will therefore be a concern. A satellite-reliant beyond-line-of-sight control network with shared bandwidth concerns some analysts. As technologies mature, a reassessment of the TCN must be conducted. Concerning management of bandwidth, Lt Gen Harry Raduege Jr., Director of the Defense Information Systems Agency, observed, “In Operation Enduring Freedom, we supported one-tenth the number of forces deployed during Desert Storm with eight times the commercial SATCOM bandwidth. Global Hawk consumed five times the total bandwidth used by the entire US military in the Gulf" (Klausner 2002, 2).

The rate at which technology evolves and matures can be forecast, but that forecast can also be wrong. It is especially important to not be overly optimistic to the point of unrealistic when setting goals. As was often observed with past programs, they were cancelled because technology had not matured to enable the project to succeed on timeline. As Congress approves budgets for programs, it wants to see results. Accurate forecasts help but it is still important to assess periodically to ensure either one, progress is being made in the right direction or two, measures of change need to be implemented. Areas of particular interest for further study relate to the maturing technologies outlined in the *UAV Roadmap 2002-2027*. The roadmap outlines sensor technologies, weaponeering, advanced fuels and propulsion systems, aerodynamic and stealth technologies, and communications be further explored and developed.

The last item recommended for further study is the position of senior leaders. Currently, the president and the Defense Department, particularly the Secretary of Defense, strongly support UAVs and related technologies. This filters down through the Chairman of the Joint Chiefs of Staff, service chiefs and secretaries, the Director of Force Transformation, Unified Commanders, and all the way to individual war fighters. In order for UAVs to endure, as current leaders move on, new leaders must take on support for their programs. The lifeblood of UAV futures lies in proving the need, gaining and maintaining support, then satisfying that need. As time passes, climate and culture can change. Will UAVs stand the test of time and proliferate as the future flying force or will they fall the wayside as expensive trendy toys? Support and vision from senior leaders play a large role in answering that question.

Many factors were analyzed in attempting to determine the answer to the future of UAVs. The research rendered an answer of neither replacement nor augmentation, but integration. A common dictionary defines integrated as “bringing together into a whole; unified. To make whole or complete by the addition of necessary parts.” In other words, to integrate is to join and coexist in and around one another. Manned and unmanned aviation will be seamless, mainstream, inseparable by distinction, and accepted as common. Several challenges to integration still exist, but can be overcome with support and direction. Concerning the future of military aviation and aviation in general, keep an eye clearly focused across the tarmac. The aircraft that taxi by may or may not have a window in the cockpit.

GLOSSARY

Air Refueling. The in-flight transfer of fuel between tanker and receiver aircraft.

Airlift. The transportation of personnel and materiel through the air providing rapid and flexible mobility.

Combat Search and Rescue (CSAR). A specific task performed by rescue forces to recover isolated personnel during war or MOOTW.

Combat Support. The essential capabilities, functions, activities, and tasks necessary to create and sustain air forces. CS includes the ability to transport, sustain, maintain, and protect the forces (personnel and materiel).

Command and Control (C2). The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. It involves both process and systems.

Counterair. Operations to attain and maintain a desired degree of air superiority by the destruction, degradation, or disruption of enemy forces.

Counterland. Air operations against enemy land force capabilities to create effects that achieve JFC objectives. The main objective is to dominate the surface environment and prevent the opponent from doing the same and includes Air Interdiction and Close Air Support.

Countersea. An extension of air capabilities into a maritime environment including specialized collateral tasks of sea surveillance, anti-ship warfare, protection of sea lines of communication through anti-submarine and anti-air warfare, aerial mine laying, and air refueling in support of naval campaigns.

Information Operations (IO). Actions taken to influence, affect, or defend information systems, and/ or decision-making to create effects across the battlespace.

ISR. Intelligence (the product resulting from the collection, processing, integration, analysis, evaluation, and interpretation of available information). Surveillance (function of systematically observing air, space, surface, or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means). Reconnaissance (obtaining specific information about the activities and resources of an enemy or potential enemy through visual observation or other detection methods; or by securing data concerning the meteorological, hydrographic, or geographic characteristics of a particular area).

Special Operations. The use of special airpower operations (denied territory mobility, surgical firepower, and special tactics) to conduct unconventional warfare, direct action, special reconnaissance, counter-terrorism, foreign internal defense, psychological operations, and counter-proliferation.

Strategic Attack. Offensive action conducted by command authorities aimed at generating effects that most directly achieve our national security objectives by affecting the adversary's leadership, conflict-sustaining resources, and strategy.

UAV. A UAV is a self-propelled aircraft that sustains flight through aerodynamic lift. It is designed to return and be rescued, and does not have a human onboard. It excludes lighter-than-air craft such as balloons, blimps, zeppelins, or airships, and it rules out ballistic missiles, which do not employ aerodynamic lift to achieve flight. Lastly, it excludes cruise missiles. Although cruise missiles are closely related ancestors to UCAVs, they differ because they are one-way platforms, where UCAVs are two-way.

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